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ORIGINAL ARTICLES.

I.—Note on New Facts relating to Eozoon Canadense.[1]

By Sir J. William Dawson, LL.D., F.R.S., etc., etc.

(PLATE IV.)

THE late Dr. Carpenter had undertaken an elaborate series of investigations of Eozoon, based on all the material collected by myself and others in Canada, with the view of preparing a complete and exhaustive memoir on the subject. In consequence of this arrangement the new facts obtained for several years have remained unpublished. Unhappily the work was left at his lamented decease in a very incomplete state.

The present note is intended, without entering into any controverted points, to notice some new facts respecting the fossil and its state of preservation, which have been disclosed within the few past years.

1. *Form of Eozoon Canadense.*

Hitherto this has been regarded as altogether indefinite, and it is true that the specimens are often in great confluent masses or sheets, the latter often distorted by the lateral pressure which the limestone has experienced. The specimen from Tudor, however, figured by Sir W. E. Logan in the 'Quarterly Journal of the Geological Society,' 1867, p. 253, and that described by me in the 'Proceedings of the American Association' in 1876, and figured in my work "Life's Dawn on Earth," gave the idea of a turbinate form more or less broad. More recently additional specimens weathered out of the limestone of Côte St. Pierre have been obtained by Mr. E. H. Hamilton, who collected for me at that place; and these, on comparison with several less perfect specimens in our collections, have established the fact that the normal shape of young and isolated specimens of *Eozoon Canadense* is a broadly-turbinate, funnel-shaped, or top-shaped form, sometimes with a depression on the upper surface giving it the appearance of the ordinary cup-shaped Mediterranean sponges. (See Pl. IV. Fig. 1.) The photographs exhibited show this appearance in two specimens. These specimens also show that there is no theca or outer coat either above or below, and that the laminæ pass outwards without change to the margin of the form, where, however, they tend to coalesce by subdividing and bending together. The laminæ are thickest at the base of the inverted cone, and become thinner and closer on ascending, and at the top they

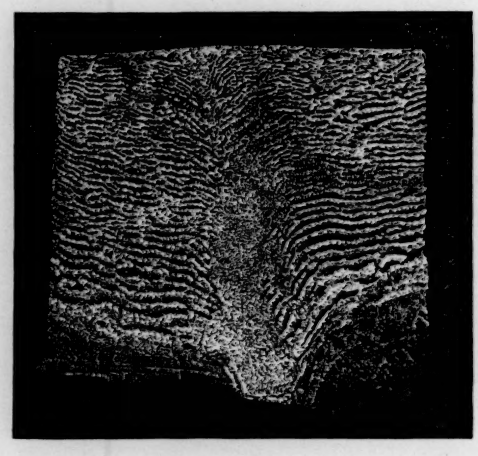
[1] Read at the Meeting of the British Association, Sept. 5, 1887.

become confounded in a general vesicular or acervuline layer. I feel now convinced that broken fragments of this upper surface scattered over the sea-bottom formed those layers of *Archæosphærinæ* which at one time I regarded as distinct organisms.

It is to be observed, however, that other forms of Eozoon occur. More especially there are rounded or dome-shaped masses, that seem to have grown on ridges or protuberances, now usually represented by nuclei of pyroxene.

2. *Pores or Oscula.*

In the large number of specimens of Eozoon which have been cut or sliced in various directions, and are now in our Museum at Montreal, it has become apparent that there are more or less cylindrical depressions or tubes, sometimes filled with serpentine and sometimes with inorganic calcite, crossing the laminæ at right angles. These seem to occur chiefly in the large and confluent masses, and are without any regular or definite arrangement. In some of the narrower openings of this kind the laminæ can be observed to subdivide and become confluent on the sides of these tubes, in the same manner as at the external surface. This circumstance induces me to believe that these are not accidental, but original parts of the structure, and intended to admit water into the lower parts of the masses. A characteristic example of a fortunately weathered specimen is seen in the photograph accompanying this paper. (See Pl. IV. Fig. 2.) A central canal of a similar kind is well shown in the accompanying illustration.



Section of the base of a turbinate or top-shaped *Eozoön*. This specimen shows an osculiform, cylindrical perforation, cut in such a manner as to show its *reticulated wall* and the descent of the laminæ toward it. Two-thirds of natural size. Coll. Carpenter.

[This illustration (from Prof. Prestwich's "Geology," vol. ii. p. 21) has been courteously lent by the Clarendon Press, Oxford.]

3. *Beds of Fragmental Eozoon.*

If Eozoon was an organism growing on the sea-bottom, it would be inevitable that it would be liable to be broken up, and in this condition to constitute a calcareous sand or gravel. I have already in previous papers described Laurentian limestones containing such fragments from the Grenville band at Côte St. Pierre, from the Adirondack Mountains in New York State, from Chelmsford, Massachusetts, and from St. John, New Brunswick, as well as from Brazil, and the Swiss Alps. Indeed, the Laurentian limestones of most parts of the world hold fragmental Eozoon. In the Peter-Redpath Museum are some large slabs of Laurentian limestone sawn under the direction of Sir W. E. Logan, and showing irregular layers and detached masses of Eozoon with layers or bands of limestone and of ophiolite. These are evidently layers successively deposited, though somewhat disturbed by subsequent movements. On selecting specimens from the white and more purely calcareous layers, I was pleased to find that they abound in fragments of laminæ of Eozoon, having the canals filled either with dolomite or with colourless serpentine. Other portions of the limestone show the peculiar granulated structure characteristic of the calcareous laminæ of Eozoon, but without any appearance of canals, which may in this case be occupied with calcite, not distinguishable from the substance of the laminæ. There are also indications in these beds of limestone of the presence of Eozoon not infiltrated with serpentine, but having its laminæ either compressed together, or with the spaces between them filled with calcite. There are other fragments which, from their minute structure, I believe to be organic, but which are apparently different from Eozoon.

4. *Veins of Chrysotile.*

I have in previous papers abundantly shown that the veins of fibrous chrysotile which abound in serpentinous limestones of the Laurentian are of secondary aqueous origin, as they fill cracks or fissures not merely crossing the beds of the limestone, but passing through the masses of Eozoon and the serpentinous concretions which occur in the beds. They must, therefore, have been formed by aqueous action long after the deposition, and in some cases after the folding and crumpling of the beds. In this respect they differ entirely from the laminæ of Eozoon, which have been subject to the same compression and folding with the beds themselves.

The chrysotile veins have, of course, no connection with the structures of Eozoon, though they have often been mistaken for its more finely tubulated portion. With respect to this latter, I believe that some wrong impressions have been created by defining it too rigorously as a "proper wall." In so far as I can ascertain, it consisted of finely divided tubes similar to those of the canal-system, and composed of its finer subdivisions placed close together, so as to become approximately parallel, as in the photograph No. 4, sent herewith.

5. *Nodules of Serpentine.*

Reference has been made in previous papers to the nodules and grains of serpentine found in the Eozoon-limestone, but destitute of any structure. These nodules, as exhibited in the large slabs already referred to, have however often patches of Eozoon attached to, or imbedded in them, and they appear to indicate a superabundance of this siliceous material accumulating by concretionary action around or attached to any foreign body, just as occurs with the flints in chalk. The layers of grains and serpentine parallel to the bedding appear to be of similar origin.

6. *State of Preservation.*

Recent observations more and more indicate the importance and frequency of dolomite as a filling of the canals, and also the fact that the serpentine deposited in and around the specimens of Eozoon is of various qualities. Dr. Sterry Hunt has shown that the purely aqueous serpentine found in the Laurentian limestones is of different composition from that occurring with igneous rocks, or as a product of the hydration of olivine. There are, however, different varieties even of this aqueous serpentine, ranging in colour from deep green to white; and one of the lighter varieties has the property of weathering to a rusty colour, owing to the oxidation of its iron. These different varieties of serpentine will, it is hoped, soon be analysed, so as to ascertain their precise composition. The mineral pyroxene, of the white or colourless variety, is a frequent associate of Eozoon, occurring often in the lower layers and filling some of the canals. Sometimes also the calcareous laminæ themselves are partially replaced by a flocculent serpentine, or by pyroxenic grains imbedded in calcite.

7. *Other Laurentian Organisms.*

In a collection recently acquired by the Peter-Redpath Museum, from the Laurentian of the Ottawa district, are some remarkable cylindrical or elongated conical bodies, from one to two inches in diameter, which seem to have occurred in connection with beds or nodules of apatite. They are composed of an outer thick cylinder of granular dark-coloured pyroxene, with a core or nucleus of white felspar; and they show no structure, except that the outer cylinder is sometimes marked with radiating rusty bands, indicating the decay of radiating plates of pyrite. They may possibly have been organisms of the nature of *Archæocyathus*; but such reference must be merely conjectural.

8. *Cryptozoum.*

The discovery by Prof. Hall, in the Potsdam formation of New York, and by Prof. Winchell in that of Minnesota, of the large laminated forms which have been described under the above name, has some interest in connection with Eozoon. I have found fragments of these bodies in conglomerates of the Quebec group, associated with Middle Cambrian fossils; and, whatever their

zoological relations, it is evident that they occur in the Cambrian rocks under the same conditions as Eozoon in the Laurentian. I find also in the Laurentian limestones certain laminated forms usually referred to Eozoon, but which have thin continuous laminæ, with spongy porous matter intervening, in the manner of *Cryptozoum* or of *Loftusia*. Whether these are merely Eozoon in a peculiar state of preservation or a distinct structure I cannot at present determine.

9. *Continuity and Character of containing Deposits.*

At a time when so many extravagant statements are made respecting the older crystalline rocks, it may be proper to state that all my recent investigations of the Middle Laurentian vindicate the results of the late Sir William Logan as to the continuity of the great limestones, their regular interstratification with the gneisses, quartzose gneisses, quartzites, and micaceous schists, and their association with bedded deposits of magnetite and graphite, and also the regularity and distinctly stratified character of all these rocks. Farther, I regard the Upper Laurentian, independently of the great masses of Labradorite rocks, which may be intrusive, as an important aqueous formation, characterised by peculiar rocks, more especially the anorthite gneisses. I am also of opinion that the so-called crystalline Huronian rocks of the country west of Lake Superior are stratigraphically, and to a great extent lithologically, equivalent to the Upper Laurentian of St. Jerome and other places in the Province of Quebec, differing chiefly in the greater or less abundance of intrusive igneous rocks.

10. *Imitative Forms.*

The extraordinary mistakes made by some lithologists in studying imperfect examples of Eozoon and rocks supposed to resemble it, and which have gained a large amount of currency, have rendered necessary the collection and study of a variety of laminated rocks, and considerable collections of these have been made for the Peter-Redpath Museum. They include banded varieties of dolerite and diorite, of gneiss, of apatite and of tourmaline with quartz, laminated limestone with serpentine, graphic granites, and a variety of other laminated and banded materials, which only require comparison with the genuine specimens to show their distinctness, but many of which have nevertheless been collected as specimens of Eozoon. I do not propose to enter into any detailed description of these here, but hope, with the aid of Dr. Harrington, to notice them in forthcoming Memoirs of the Peter-Redpath Museum.

Postscript.—It has been suggested by Mr. Julien[1] and others that Eozoönal structure may be due to the alternation of mineral layers formed in the passage-beds between concretions and their enclosing mass. The objections to this view are :

1. Laminated passage-rocks and laminated concretionary forms

[1] Proceed. Amer. Assoc. vol. xxxiii. 1884, pp. 415, 416.

have only simple laminæ, whereas *Eozoon* has connected or reticulatory laminæ.

2. Laminated passage-rocks have no structure other than crystalline. *Eozoon* has beautiful tubulation in its calcareous walls, besides large tubes or oscula.

3. Sometimes (not usually) pyroxene is the siliceous part of *Eozoon*; or, as we hold, the mineralizing agent. More usually it is serpentine, sometimes loganite, or dolomite, or mere earthy limestone. It is not possible that all these minerals should assume the same forms.

4. Pyroxene and serpentine both occur in nodules and bands in the Laurentian limestones, and in most cases without any traces of *Eozoon*, while *Eozoon* occurs in the limestone remote from such nodules and bands, where no passage of any kind can occur, and presents distinct forms.

5. There are only two localities known to me, one in a quarry near Côte St. Pierre, and one at Burgess, where a bed with badly-preserved *Eozoon* occurs in a manner which would not even suggest an idea. Pyroxene is present in the one case, and loganite in the other.

6. I have often thought of this suggested explanation, and have compared *Eozoon* with all sorts of banded and passage-rocks taken from the Laurentian and other formations, but have seen no reason to adopt such a view for *Eozoon*. I may add that in the Peter-Redpath Museum at Montreal I have accumulated a very large number of laminated and passage-rocks and concretions for purposes of comparison.

7. How on such an hypothesis can we explain the beds of limestone composed of or filled with fragments of *Eozoon*?

EXPLANATION OF PLATE IV.

Fig. 1.—Small specimen of *Eozoön*, separated from the matrix, and showing a turbinate form. Nat. size. Coll. Dawson.

Fig. 2.—Weathered specimen of *Eozoön*, showing a section through the middle, with two cylindrical, osculiform, vertical tubes. The modification of the laminæ at the sides of the tubes is similar to that at the exterior. Nat. size. Coll. Dawson.

II.—Observations on the Rounding of Pebbles by Alpine Rivers, with a Note on their Bearing upon the Origin of the Bunter Conglomerate.[1]

By Prof. T. G. Bonney, D.Sc., LL.D., F.R.S., F.G.S.

WHEN preparing my address to Section C in 1886, I had much need of information as to the amount of rounding which takes place in rock fragments when transported by rapid streams. Useful information and references are given in Dr. A. Geikie's Text Book[2] and in De Lapparent's "Traité de Géologie,"[3] and there are the ex-

[1] A Paper read at the Meeting of the Brit. Assoc. (Section C) in Manchester, 1887.

[2] Book iii. pt. ii. sec. ii.

[3] Book ii. sec. i. ch. iii.

perimental researches of Daubrée in his "Géologie Experimentale";[1] but from neither these nor other sources (so far as known to me) could I obtain what I wanted. I must, however, admit that I am less familiar with the talus heap of geological literature than I should be, and prefer making observations in the open air, to hunting for records of them in a library. So, as I had some opportunities of doing the former during my journey last summer, I record the results in the hope that they may be useful to others; first heartily thanking my companion, the Rev. E. Hill, for constant co-operation and assistance.

These observations may be arranged roughly in three groups, which correspond with the three stages in the physical history of an Alpine river. It begins as a series of torrents, born for the most part high up on the mountain side from snow-bed and glacier. Its next stage is that of a single torrent rushing over the bed of an Alpine valley, still bounded on either hand by mountain ranges; the third, and last for our present purpose, begins as it issues from the 'gates of the hills' and commences its journey through the lowland plains. In the first of these stages its fall is always rapid, as it leaps from ledge to ledge, or even from crag to crag, descending not unfrequently at average rates of 250 feet to 500 feet in a mile, or along slopes averaging from 3 to 6 degrees. Thus it is a rushing roaring cataract, able always to sweep along boulders full a couple of feet in diameter, and often much larger blocks. In the second stage the fall becomes more gentle, though occasionally, especially at the commencement, there may be a partial return to the former conditions; tributary streams also are being constantly received, which have only passed through that stage; but gradually as the valley widens the torrential character is lost, and the river flows as a strong swirling stream, in which intervals of actually broken water are rare. Lastly, after emerging from the mountains, and thus being cut off from all further contributions from torrents, it sweeps along with a strong steady flow, "hasteless but restless," perhaps one of the grandest representations of unobtrusive power that can be seen in Nature.

Obviously in observations of the present kind, little more than general results can be given. A river is constantly receiving tributaries, which discharge into it materials, not only differing in hardness or tenacity, but also in the amount of detrition which they have undergone. The strength also of its current varies from time to time. In some districts, or at certain seasons, what in the morning was a dry stream-bed, in the afternoon may be a roaring torrent. Further it is extremely difficult to determine the velocity with which a mountain torrent flows. In the case of some of the larger and less rapid rivers we made rough estimates by watching floating bits of wood and the like; they varied from about $2\frac{1}{4}$ to $4\frac{1}{2}$ miles an hour. An approximation also may be made from observing the size of the pebbles in the bed. A table is quoted in most text

[1] Vol. i. sec. ii. ch. i.

books which may be thus extended theoretically for pebbles formed of an average rock.

Diameter of pebbles just moved.	Velocity of stream.
1 inch.....	2 feet per second, 1·3638 miles an hour.
2 inches	2·82 feet ,,
3 ,, ...	3·46 ,, ,,
4 ,, ...	4·00 ,, ,, 2·7276 ,, ,,
5 ,, ...	4·47 ,, ,,
6 ,, ...	4·90 ,, ,,
7 ,, ...	5·29 ,, ,,
8 ,, ...	5·65 ,, ,,
9 ,, ...	6·00 ,, ,, 4·0914 ,, ,,

Hence we may infer that a deposit in which fairly well-rounded pebbles of about 4 inches diameter are so common as to be characteristic, is the result of a stream which flowed pretty steadily at a rate of about $2\frac{3}{4}$ miles an hour, and one in which they are about 8 inches or 9 inches diameter, is the result of a stream flowing about 4 miles an hour. It must, however, be remembered that this would be the velocity at the bottom of the stream, which is estimated at about half that of the surface in the middle. Great variability in the size of the pebbles, and especially the presence of frequent boulders or subangular blocks much exceeding the average size,—as, for example, a mixture of blocks something like two feet in diameter, with pebbles generally not more than one foot in diameter, and commonly less,—is indicative of torrential discharge.

For brevity I use the term 'Alpine rock' to mean gneisses, more or less granitoid, and mica-schists of various kinds, together with hornblendic or chloritic schists, and possibly serpentines—that is to say rocks, which are in all cases crystalline, and in some at least of igneous origin.

Group I.

Bed of Romanche above Villard d'Arêne (Dauphiné).—This stony plain lies at a height of about 5000 feet above the sea—at the foot of a steep descent of 1500 feet. The river is fed by streams from snow-beds and glaciers, and its sources may be roughly estimated as from 7000 to 8000 feet above the sea, and at distances of three to five miles[1] from the place of observation. The stones are chiefly granitoid rocks, but some are Jurassic mudstones (these are from near at hand). Leaving the latter out of consideration, the stones, which vary from boulders downwards, are generally subangular, even the smaller pebbles not being well rounded.

Bed of torrent through village at Windisch Matrei (Tyrol).—This comes down from the valley running up to the Kalser Thorl, and probably has descended some 2000 feet. The 'torrential' character is indicated not only by the variability in the size of the stones and boulders, but also by the high walls which protect the village from its ravages. Stones from 3 ins. to 6 ins. diameter were common; others up to about a foot diameter were fairly common, and larger occurred.

[1] Distances in this paper, unless otherwise stated, are measured on a map, and so are obviously less than the actual course of the stream.

Well-rounded pebbles rare, and never large. Alpine rock, including some serpentine.

Little plain at foot of Gross Venediger.—Enclosed by craggy mountains; stones brought down by various torrents, chiefly from snow-beds and glaciers, descending precipitously from 1000 to 2000 feet. Boulders and pebbles of Alpine rock, the latter not much rounded, having generally little more than the corners worn away; only some of the smaller and softer are moderately rounded.

Bed of Stillupthal (Zillerthal).—Glaciers and snow-beds surround the head of the valley, the floor of which rises rather gradually. Deposits torrential in character. Alpine rock. Observation at 3500 feet, where the stream flowed with only a slightly broken surface. Stones subangular to imperfectly rounded, mostly 3 ins. to 4 ins. in diameter, a few nearly a foot. A couple of miles or so lower down, at a height of 2950 feet, the flow is more rapid: many pebbles 3 ins. to 4 ins. in diameter, varying from rounded subangular to subangular rounded, together with larger boulders of all sizes up to at least a yard diameter, some of which were moderately rounded; chiefly gneiss and granitoid rock.

Below Ginzling, Zillerthal.—Place of observation about 3230 feet: the river being formed by confluence of a torrent from the Floitenthal (a glen about nine miles long, enclosed by steep mountain walls, seamed by cascades and rising at the upper end from 9000 feet to 11,000 feet, and terminated by a rapid descent through a rocky gorge) and that from the Zemmthal (a valley perhaps three miles longer, which rises on the whole more gradually, and is enclosed by mountains somewhat lower). Materials, various Alpine rocks. All sizes up to about a foot in diameter common, but many exceed this; blocks up to two or three feet diameter not being rare: much variability in the amount of rounding, many being quite subangular, but some fairly well rounded,[1] these chiefly a rock resembling a tonalite not rich in quartz and a felspar-actinolite rock (rather rare). The former I believe occurs *in situ* far back in both these glens.

Group II.

We may commence by following the course of the river last described. At Mairhofen (2096 feet) by the Calvarienberg, stones commonly 4 ins. to 6 ins. diam., but both smaller and larger, are present; some blocks are quite a yard in diameter. Amount of wearing very variable; almost the only well-rounded pebbles are the above-named 'tonalite'; next to that is a porphyritic gneissoid rock, common in the Stillupthal. Alpine rocks, with some subcrystalline limestone.

At Zell (four miles and a half and more than 200 feet lower down). Stream strong, surface rather broken in the swifter parts. Stones mostly from rounded subangular to fairly rounded, commonly from about 4 ins. to 6 ins. smaller of course occur, but rarely one over

[1] It must be remembered that when a torrent descends precipitously over a bed of rock, not a few stones may receive an exceptional amount of rounding by being whirled about in 'potholes.'

1 foot diameter. Mostly granitoid gneisses of a somewhat friable character.

I have in my note book observations of the Inn at Jenbach, Innsbruck, and near to Landeck, of the Isel between Windisch Matrei and Lienz, of the Drave at the latter place, of the Eisack near Brunecken, and at Bozen, of the Romanche at Vizille, and the Isère at Grenoble; but it is perhaps needless to quote them in detail, as to a great extent they would be repetitions of the above statements. Suffice it to say the stones commonly range from about 3 ins. to 6 ins., smaller and larger occurring, in the latter case not seldom up to nearly 1 foot, with occasional large boulders; that the amount of rounding is variable, but the majority of the first named may be described as from subangular to moderately rounded—well-rounded pebbles being generally not common.[1] Materials, Alpine rocks with variable amounts of limestones and grits. At Bozen also the igneous rocks of the district were well represented.

Group III.

The first case examined was the Po at Turin. The river and its tributaries have now flowed over about 35 to full 50 miles of plain. The principal streams which feed it descend valleys from about 15 to over 30 miles long, and may be reckoned as having their sources at from 5000 to 6000 feet above the sea.[2]

The stones exposed near the banks consist chiefly of Alpine rocks, are commonly 3 ins. to 4 ins. diameter, occasionally running up to about 8 ins. together of course with smaller. As a rule they are not well rounded, retaining more or less a subangular outline, though the corners and edges are worn off.

In travelling from Turin to Milan, and thence to the Lago di Garda, several rivers are crossed, and sections obtained of the substratum of the great alluvial plain of Piedmont and Lombardy. The results in regard to the former may be summarized in a tabular form.

Name.	Approximate length of river.		Diameter of Pebbles.		Condition.
	Among the Mts.	Over the plain.	Average.	Maximum.	
Stura ...	18 miles.	20 miles.	3″ to 4″	? 6″	Often fairly rounded, but many still subangular.
Orco.....	22 ,,	18 ,,	abt. 4″	6″	Fairly well rounded.
Sesia ...	25 ,,	35 ,,	abt. 2″	rarely > 4″	Moderately ,,
Ticino ...	...	20 ,,	3″ to 4″	?	,, ,,
Adda ...	...	20 ,,	3″ to 4″	? 6″	Fairly well ,,

The main streams of the Ticino and Adda have most of their Alpine pebbles stopped by the Lakes of Maggiore and Como, but

[1] Our estimates of the rates of flow varied from about three to four and three-quarter miles an hour. I expect these great mountain rivers run at an average pace of nearly four miles an hour, and at certain seasons considerably exceed this.

[2] I mean as fairly strong streams; in some cases brooklets would be higher, and of course the snow-beds about the sources of the Po rise up in places to quite 9000 feet.

they receive some sub-Alpine tributaries. Consequently, limestone pebbles characterize their gravels.

Besides these observations we repeatedly had indications of the gravel of the great plain, either from the stones scattered over the fields, from ballast pits, or from railway cuttings. Here also pebbles often about 3 ins. or 4 ins. are common, with occasional larger ones. In fact, they frequently are very similar in size to those of the Bunter Conglomerate in Staffordshire, but generally not quite so well rounded. Limestone becomes more common, as might be expected, as we proceed eastwards. This remark holds, I believe, of the great plain of Lombardy as far as the south end of the Lake of Garda.

Old drifts, repeatedly seen between Lyons and Grenoble, in size, amount of rolling and arrangement, bore a remarkable resemblance to the Bunter pebble-beds of Staffordshire (except that the materials were mainly limestone). This was particularly the case near Virencal, where the section was some 50 feet high, and the pebbles were parted by streaks or bands of sand. The old drifts of the Rhine at Stein and near Bale are very similar.

In regard to the Lake of Garda, I endeavoured to ascertain the action of its waves on the beach pebbles. These are abundant to the east of Desenzano, and they have evidently been derived from the north. They are fairly well rounded, but seeing that similar pebbles, about as well rounded, occur in the drifts of which its banks consist, no inference can be drawn from them. But I observed that well-rounded pebbles had been formed on the shore from fragments of a soft red brick; also that shards of ordinary red earthenware had been sometimes fairly well rounded. It must be remembered that the Lago di Garda is noted of old for its waves, "fluctibus et fremitu assurgens, Benace, marino;" but, as a rule, the great sub-Alpine lakes have not, so far as I have noticed, much effect on rock fragments.

It is difficult to give precise statements of the amount of fall in the Alpine rivers; but the following are rough approximations, calculated from the heights quoted in guide-books, which of course do not give the exact level of the river at the place, and from the distances by road, which, at any rate when the valley is tolerably level, are generally rather sometimes considerably shorter than the river course.

The Inn, from St. Moritz to Samaden (three miles) falls about 65·3 feet per mile; from Samaden to Landeck (79½ miles) about 37·3 feet per mile; from Landeck to Innsbruck (52¾ miles) about 13·8 feet per mile; from Innsbruck to Jenbach (23 miles) 3·8 feet per mile (I believe rather more, for I think the height given for Jenbach is above the Inn—possibly 80 or 100 feet too great).

The Ziller from Ginzling to Mairhofen (about 7½ miles) falls 155·5 feet per mile; from Mairhofen to Zell (4½ miles) 17·8 feet per mile; from Zell to Jenbach about 4·6 feet or a little more (this, for the above reason, and as the embouchure of the Ziller is not at Jenbach itself, is a very rough estimate).

The Isel (including a tributary) : Tauern Haus to Windisch Matrei (about 10½ miles) about 164 feet per mile; Windisch Matrei to Lienz (18 miles) 58 feet per mile.

It is very difficult to estimate the fall in the Po and its tributaries. Turin is 602 feet above the sea, probably the edge of the plain is about 800 feet. That would give a fall of about 4 feet per mile. In the tributary valleys I should think that the fall would be not less than 100 feet per mile. As an example of a true torrent, the Reuss between Andermatt and Amsteg falls about 212 feet per mile; from the latter place to the Lake of Lucerne only 26·3 feet per mile.

The facts thus collected appear to me to warrant the following conclusions :—

1. The rapidity with which a pebble is formed depends *cæteris paribus* on the nature of the rock.

2. Pebbles are rounded with comparative rapidity when the descent is rapid; that is, when they are dashed down rock slopes by a roaring torrent, capable of sweeping along blocks of far greater size.

3. Pebbles are rounded with comparative slowness when the descent is gentle, and the average pace of the river is just about able to push them along its bed.

4. As indicated by Daubrée's interesting experiments, the process of rounding *cæteris paribus* always goes on more rapidly at first.

In the above observations the rocks (with the exception of some vein-quartz which generally proved a rather intractable material) may be taken as ranging in hardness from rather above 3 to about 6. The limestone pebbles would probably range from 3 to 4, and there would be chemical action in addition. The Alpine rocks, as a rule, would probably range from 5 to 6, for though quartz is present, there is always a good amount of felspar or mica. The easy rounding of the more micaceous schists, due to their softness, is to some extent counteracted by their fissility.

If, then, we find in any conglomerate, a large number of well-rounded pebbles of a rock not less hard than felspar, we are justified in concluding that they are the deposit of a river which, in any case, has had a course of several miles, and has either descended as a very rapid stream from snow-capped mountains of considerable elevation, the detritus, in short, of a strong, full, torrent in a valley running down from a great mountain-chain, or of a river which, rising at a more moderate elevation and swollen by many tributaries, has flowed for a very much longer distance. Perhaps we might venture to say, as a rough standard of comparison, that the effect of a thousand feet of rapid descent is equivalent to that of the more leisurely traverse of at least twenty miles, so that fairly well rounded pebbles of a rock with hardness not exceeding 6 signify at least either a rapid descent of three thousand feet or a journey at a less speed of sixty miles.[1]

[1] Prof. Daubrée (Géol. Experim. vol. i. sec. ii. ch. v.) obtained experimentally a distance of a little less than 16 miles for the manufacture of a rounded pebble of granite, but this must be regarded as the least possible distance, for in his experiments the fragments would be knocked one against another much more than in transport by a stream, except perhaps in a "pothole."

If then we consider the question of the origin of the Bunter pebbles in the light of these facts, two suggestions as to their origin are at once shown to be impossible. The majority of the pebbles are a very hard quartzite, are from 2 ins. to 4 ins. diameter, and are well rounded. Hence they must have had a much longer descent or a much longer journey than that above named.

By one author they have been referred to a concealed ridge of Palæozoic rock in Eastern England,[1] by another to a similar ridge in Central England, of which the Malvern and Lickey Hills, etc., are the monumental outcrops.[2] I have already pointed out the difficulties attending both these views, so far as regards the nature of the materials, their enormous volume and their disposition. I have commented on the confused views of the latter author, both as to lithology and physical geology; but the observations above made effectually dispose of one of his criticisms, that pebbles coming from Scotland would have been "reduced to sand" before reaching Staffordshire,—a criticism indeed which even the knowledge in our possession at that time did not justify. They also indicate that unless we maintain the Bunter Beds to be a marine deposit (which I do not suppose will find any support with modern geologists), its pebbles can only have been formed by strong and full rivers. These, if from insular lands, must have issued from lofty mountains; if from continental, must have flowed with strong stream for long distances. Considering the hardness of the materials, we may demand insular mountains even higher than the Alps, or rivers with courses exceeding a couple of hundred miles in length, of fuller volume and stronger stream than now exist in Britain. The sources for the Bunter pebbles then, proposed by either of these authors, Utopian at best, cannot be made to accord with the facts which I have recounted, while the general resemblance of the Bunter Beds to the conglomerate of the Nagelflue, and to the gravel of the plains which stretch away from the feet of the Alps, renders the northern origin of these pebbles,—where continental conditions did prevail and identical pebbles still exist in older conglomerates—a far more probable theory.

III.—The Gneissose Granite of the Himalayas.

By Colonel C. A. McMahon, F.G.S.

I HAVE read with great pleasure Mr. R. D. Oldham's interesting article in this Magazine, for October, 1887, on the gneissose rocks of the Himalayas. Mr. Oldham concurs with me in assigning an eruptive origin for the more or less gneissose rocks at Dalhousie, the Chor, and for almost all those in the Satlej Valley; and as I have in my published papers expressly intimated "my belief that some of the crystalline rocks of the north-western Himalayas are metamorphic gneisses" (Records Geol. Surv. India, vol. xviii. p. 110), I see no grounds for dissenting from his observations regarding the latter class of rocks.

[1] Geol. Mag. Dec. II. Vol. X. p. 285.

[2] Proc. Phil. Soc. Birmingham, vol. iii. p. 157; Geol. Mag. Dec. II. Vol. X. p. 199. This locality is practically included in the other.

One remark, however, in Mr. Oldham's article, tempts me to offer a few words of explanation in continuation of my last paper in the GEOLOGICAL MAGAZINE. Speaking of the gneissose-granite, Mr. Oldham expresses his belief "that the very slight foliation of the larger masses is principally a fluxion structure, while the more developed structure of the thinner bands, and near the margins of the larger masses, was produced in the solid but *still heated granite* [the italics are mine] by the same causes—whatever they be—that led to the foliation of the adjacent sedimentary beds;" and in a footnote he remarks; "In 1884 Colonel McMahon seems to have held an opinion somewhat similar to this (see Records Geol. Surv. India, vol. xvii. p. 72), but so far as I can understand his paper in the May Number of this MAGAZINE, he has now abandoned it."

I hoped that I had made my meaning sufficiently clear; but as this does not appear to have been the case, a few explanatory remarks may not be out of place. The passage in my paper published in the Records Geol. Surv. India referred to runs as follows:—"The conclusion at which I have arrived, on a consideration of all the facts of the case, is that the invasion of previously metamorphosed strata by gneissose granite, combined with the pseudo-foliation of the latter due to the pressure of hard strata on a partially cooled and imperfectly viscid rock, has imparted to the intruded rock the superficial appearance of being a member of the same metamorphic series as the schists and slates into which it has intruded. There is no inconsistency, I would point out in conclusion, in supposing that the rock which gives evidence of having passed through a stage of aqueo-igneous fusion was partially cooled and semi-viscid when[1] actually intruded into the schists. Observation in our own time shows that there are pauses and long intervals in volcanic action; and doubtless similar pauses took place in plutonic action during which the cooling and partial consolidation of igneous masses went on and the larger porphyritic crystals found in many of them were formed. The subsequent motion of a partially consolidated viscid rock and its intrusion as a sheet between hard strata, or between the walls of a fault, would, it seems to me, naturally produce parallelism of structure, or pseudo-foliation, as long ago pointed out by Scrope and Naumann."

I have not gone back one iota from the view expressed in the above extract, and I am at a loss to understand why I should have been supposed to have done so. The observations given at pp. 219, 220, of the 1887 volume of this MAGAZINE, seem to me to be merely a detailed explanation of the view more briefly expressed in the above extract. In the latter three conditions are noted; the partial consolidation of the granite before it was moved into place, traction action on the granite when it was squeezed into position; and the "pressure of hard strata" upon the intruded mass.

That partial consolidation had set in before the granite was moved into its present position seems implied by the pronounced porphyritic character of the rock. "All the facts connected with

[1] In the Records the word is *where*—a senseless alteration of the text due to the Indian printer's devil.

these porphyritic lavas," writes Professor Judd with reference to a somewhat different class of rock in his well-known work on Volcanoes, p. 256, "points to the conclusion that while the crystals in their ground-mass have separated from the liquefied materials near the surface, the large embedded crystals have floated up from great depths within the earth's crust, where they had originally formed." I do not mean to affirm that a similar inference would be safe in respect of all porphyritic rocks, plutonic as well as volcanic; but I think we may safely draw that inference with regard to the porphyritic crystals in the Dalhousie rock, for in some places tongues, and veins, intruded into the adjacent schists are as distinctly porphyritic as the main mass of the granite (Records Geol. Surv. India, vol. xv. p. 45), and I do not think any one would allege that the large porphyritic crystals in the small veins were formed *in situ*. The same conclusion must, I think, be arrived at when large porphyritic crystals are found (Records Geol. Surv. India, vol. xvi. p. 129) in a matrix so fine grained that the Dalhousie rock occasionally assumes the superficial appearance of a felspar porphyry.

That the granite was, at the time of intrusion, partially cooled and imperfectly viscid, is almost conclusively proved by the condition of the foreign fragments included in it. At page 175 of the volume to which Mr. Oldham has referred (vol. xvii. of 1884) I wrote as follows:—"In the case of the long splinter of schist, a fragment of which is depicted in the plate attached to this paper, it is clear that it must have been included in the granite when the latter was already partially consolidated, and had lost a considerable part of its heat. I have found on other grounds, in my previous papers, that the gneissose-granite had partially consolidated before it was intruded into the stratified rocks; and the evidence afforded by the fragment of schist under consideration confirms this conclusion. The schist would not have retained its fine foliation had the granite been in a fluid state, and at the high heat indicated by that condition." The reasons for coming to this conclusion are given in detail in my paper.

I may note in passing that the texture of the porphyritic granite immediately round the fragment of schist referred to is fairly granitic, and this fragment proves that the rock from which it was torn was in a foliated condition before the intrusion of the granite took place. The granitic structure of the granite compared with the fine foliation of the schist, a point that is well brought out by the heliogravure reproduction of a photograph given at p. 175, vol. xvii. Records Geol. Surv. India, appears to negative the assumption that the foliation of the Dalhousie granite and the foliation of the schists into, and through which, it was intruded, are both alike due to pressure-metamorphism operating *after* the intrusion of the granite.

From the use of the words "still heated granite," and from the context, I am under the impression that Mr. Oldham is of opinion that the structural changes in the granite which resulted in foliation were produced before it had perfectly cooled down after its injection; if so, our views seem to be substantially identical.

Whether he holds that the granite was injected in a fluid, or in a partially consolidated condition, is not so clear to me. Possibly if there is any apparent divergence in our views, it may be owing to my not having expressed mine in sufficient detail.

Mr. Oldham, in the extract I have quoted, speaks of the condition of the granite when foliation was produced as "*solid* but still heated." (The italics are mine.) In my papers I have avoided the use of the word solid, and preferred to speak of the granite as being in "a partially cooled and imperfectly viscid" condition, or as an "imperfectly consolidated" mass; but by the use of these expressions I contemplated a considerable advance towards solidity. In my article in the May, 1887, number of this Magazine, I stated that the "semi-plastic mass was subjected to enormous pressure; the mica was crumpled, and the crystals of felspar were cracked and ruptured." These results, I need hardly say, could not have been produced unless the solidification of those portions of the rock in which they are to be observed was in a somewhat advanced stage. But, on the other hand, I do not think it necessary to hold that the granite at the moment of intrusion was everywhere in a state of maximum viscidity. Its condition, I apprehend, varied from point to point; being in some places in the normal condition of a liquefied granite, whilst at others it was almost completely made up of minerals that had already crystallized out of the magma. There were also, we may suppose, numerous gradations between these two conditions. That this was actually the state of the granite I infer from the examination of thin slices under the microscope, and from the appearance of the rock in the field. In some places it is a perfect granite—in others it is a perfect schist. In specimens from some spots the microscope reveals the marks of crushing; in those from other localities these marks are absent.

At pages 76–77 of the February, 1887, number of this Magazine, I have suggested a few reasons to account for a similar state of things in the Lizard gabbro. The rapid, and often apparently capricious, passage of rocks of this class from a granitic to a foliated condition, suggests very complex questions which cannot be discussed in detail on the present occasion; but though I shall not now attempt to explain at length why traction, shear, and pressure, operating on an imperfectly consolidated eruptive rock, fail to produce perfectly uniform results in every portion of the erupted mass, still, it may be as well to briefly allude to some of the causes which, in my opinion, may have produced these results in the Dalhousie granite. One reason has already been alluded to, namely, the want of uniformity in the consistency of all portions of the erupted mass at the moment of eruption. Micro-petrologists are already familiar with the idea that a more or less complete liquefaction of deep-seated igneous rocks takes place when the pressure under which they have been held is relaxed by portions of these rocks finding a vent at the surface;—instance the partial refusion of the porphyritic quartz crystals in quartz porphyries. The order in which minerals fuse, or crystallize, depends, to mention one factor

only, on pressure; and, in the case of the Himalayan gneissose-granite, pressure must have varied considerably from point to point within the area of eruption.

The high probability that the rising granite varied in its consistency in different portions of its mass at the time of intrusion must not be lost sight of in dealing with a rock that occurs within an area that extends not for hundreds of feet, or hundreds of yards even, but for hundreds of miles.

If other causes besides the absence of perfect homogeneity at the time of intrusion are wanted to account for the variation of structure to be observed in the rock, the following may be mentioned:—At the points where shearing was most severe, secondary heat was probably developed, and the resulting chemical and mineralogical action may have been considerable. Then, again, we cannot suppose that the earth-movements that produced the contortion, overfolding, and faulting of the strata were sudden and explosive in their character; doubtless they were due to long-sustained compression, and the movements that resulted from this compression were repeated—possibly with considerable rests, or intervals between—during long periods of time. Each of these movements probably left its mark upon the rocks, and who is now to discriminate between the effects of the shear, traction, and pressure that accompanied the actual act of intrusion, and the shear and pressure caused by the earth-movements that must, in many cases, have followed the act of injection and have sheared and nipped the gradually cooling granite with a pressure that not only varied locally from place to place, but was applied again and again *during successive stages of consolidation?*

When I penned the article which appeared in your May, 1887, Number, the object I had chiefly in view was to show that the foliation of the granite of the N.W. Himalayas was due to pressure acting on an imperfectly consolidated intrusive rock prior to its complete consolidation, and that it was not due to pressure-metamorphism exerted on a solid and cooled rock after it had attained a consolidated and crystalline condition. In short, that it was an incident in the history of the eruption, and was not, like cleavage, due to pressure exerted on a solid rock. The theory of pressure-metamorphism differs materially from the explanation I have advocated to account for the foliation of the granite of the N.W. Himalayas. The former is not concerned with a phase of the consolidation of an eruptive rock. Pressure-metamorphism may come into action whole geological ages after the last stage of the intrusion of an igneous rock has come to an end; and may operate on rocks of purely sedimentary origin. Whether or not pressure-metamorphism applied to solid rocks is capable of producing all the results alleged by the extreme advocates of the theory, is a question foreign to the present inquiry. All that I have contended for is, that, in the regions embraced by my papers, pressure applied to the granite *after* its complete consolidation was not the cause of its foliation, but rather pressure applied whilst it was yet in a more or less plastic condition.

IV.—On the Mineralogical Constitution of Calcareous Organisms.[1]

By Vaughan Cornish and Percy F. Kendall,
Berkeley Fellow of the Owens College.

Introduction.

In Mr. Sorby's presidential address at the anniversary meeting of the Geological Society in 1879, attention was drawn to the fact that the carbonate of lime in calcareous organisms is in certain cases in the form of calcite, in others of aragonite, and various genera of such organisms were classed according to their mineralogical constitution. It was also shown that aragonite fossils are of greatly inferior stability to those formed of calcite, in many deposits casts only of aragonite fossils being preserved, whilst those of calcite remain unaltered. In the same address Mr. Sorby insisted on the importance of this difference of stability as affecting the trustworthiness of the geological record.

The idea that the disappearance of aragonite fossils is due to the action of carbonated water naturally suggests itself; at the same time no experimental data appeared to exist which would lead one to suppose that calcite would be acted upon less readily than aragonite by a solution of carbonic acid.

Part I. of the present paper contains *an account of the experimental evidence obtained as to the cause of the inferior stability of aragonite fossils as compared with those formed of calcite, with observations on the geological conditions favourable to the removal of aragonite fossils.*

It was pointed out by one of us in a paper in the Geological Magazine, Nov. 1883, that *those shells classed by Mr. Sorby as calcite are characterized in the fossil state by a compact texture and by translucency, whilst the aragonite shells are opaque and of a chalky appearance,* and the opinion was there stated that these characters would be found sufficiently constant to be of use in determining the zoological position of obscure forms.

Part II. of the present paper contains *an account of the work done in following out the above observation, and in the examination of certain organisms belonging to groups not yet classified according to their mineralogical constitution.*

Part I.

Two fossil shells, *Pecten opercularis* (calcite) and *Pectunculus glycimeris* (aragonite) were selected, not differing greatly in weight, and presenting nearly the same extent of surface. The aragonite shell was a specimen entirely unacted on, with a hard compact surface. These shells were suspended in a solution of carbonic acid, removed from time to time, weighed, and then placed in a fresh solution of carbonic acid. The experiment was only discontinued when the aragonite shell fell into fragments.

[1] An Abstract of this paper was read before Section C. of the British Association at Manchester, September, 1887.

Three circumstances were noted, viz. :

1. That the calcite shell lost in weight through solution of its substance, but retained its compact texture and translucency, so that no alteration in appearance could be observed till it had lost a large percentage of its substance.

2. That the aragonite shell lost by solution between two and three times as great a percentage of its weight as was lost by the calcite shell.

3. That the hard compact surface of the aragonite shell speedily disappeared, the shell assuming a consistency similar to that of kaolin, and falling into fragments after losing 60 per cent. of its weight by solution.

Experiments with other aragonite shells showed that after a short period of subjection to carbonic acid solution they are reduced to a consistency such that the substance of the shell comes away with a touch, and such that a gentle stream of water is sufficient entirely to disintegrate the shell. Calcite shells, on the other hand, after being acted upon lose only a small quantity of substance by washing. In the Coralline Crag we have observed them in a pulverulent state only in those portions from which the aragonite shells have been entirely removed.

From observations 2 and 3 it follows that carbonated water acts so as to decompose aragonite fossils more readily than those formed of calcite, and from 3 it further follows that where water is free to circulate, the aragonite fossils already acted upon lose their coherence and are reduced to the condition of a powder.

In addition we see from 1 that the retention of their compact structure and translucency by calcite fossils lends to them an appearance of immunity from the action of carbonic acid which they do not in reality enjoy.

It remained to investigate the cause or causes of observation 2, and to ascertain whether the fact observed, viz. that aragonite shells are dissolved far more rapidly than the calcite, is due (*a*) to difference of mineralogical constitution; (*b*) to difference of structure of the shell related to that difference of mineralogical constitution; or (*c*) to both causes combined.

To test the first point we placed pure crystalline calcite and aragonite in fine powder in two flasks of the same capacity and shape together with equal volumes of carbonic acid solution of equal strength, and determined the loss of weight suffered by the substances after the lapse of an equal interval of time in each case.

The result of the experiment showed no excess of action on the aragonite over that on the calcite.

A similar experiment where finely powdered fossil calcite and aragonite shells were employed gave similar results.

The conditions under which these determinations were made were not such as to eliminate certain possible sources of error, but the degree of accuracy obtainable is sufficient to justify us in concluding from the numbers given below that the more rapid solution of aragonite fossil shells is not due directly to difference of mineralogical constitution, but to difference of structure.

In the case of the experiment where the fossil shells were suspended in carbonated water the percentage of loss is calculated on the weight of the shell before its immersion in the carbonic acid solution in each case, and not on the original weight. It will be observed from the numbers given that the ratio between the losses by solution increases towards the end of the experiment when the aragonite shell had assumed a clayey consistency.

Experiment with fossil shells suspended in CO_2 solution :—

Nature of Subst.	Original Wt.	Loss after 70 hrs.	After other 48 hrs.	After other 74 hrs.
Calcite	·3196 grams.	12·60 %	7·12 %	9·44 %
Aragonite...	·3779 ,,	26·35 %	17·18 %	27·13 %

Experiment with fossil shells in a state of fine powder :—

Nature of Subst.	Original Wt.	Loss in Wt.	% of Loss on Original Wt.
Calcite	·5694 grams.	·0829 grams.	14·56
Aragonite ...	·6010 ,,	·0858 ,,	14·27

Experiment with powdered crystals :—

Nature of Subst.	Original Wt.	Loss in Wt.	% of Loss on Original Wt.
Calcite	·5850 grams.	·0404 grams.	6·90
Aragonite ...	·6170 ,,	·0350 ,,	5·65

With regard to the question of structure, aragonite fossil shells have a hard surface, but the interior, though close-grained, is porous. The calcite shells on the other hand are compact throughout. The porosity of the aragonite fossils is indicated by the circumstance that they adhere to the tongue. The difference of structure is well shown by the following experiments. If a fossil calcite shell be immersed in water a few large bubbles collect on the shell, and after a time detach themselves one by one. On the other hand, if an aragonite fossil from which the hard outer layer has been removed be immersed, a stream of small bubbles rises rapidly from the shell, giving an appearance of effervescence similar to that produced by the action of a dilute acid on carbonate of lime.

The geological conditions favourable to the removal of aragonite shells appear to be :

(*a*) Enclosure in permeable beds.

(*b*) *Flow* of carbonated water.

The latter condition can of course be best complied with above the saturation level of the rock. This is well illustrated by the following observation made at the Coralline Crag pit belonging to Mr. Pettit, on the Leiston road, near Aldborough, referred to in the paper already cited (Geol. Mag. Nov. 1883). Here, above the saturation level, aragonite shells have entirely disappeared, casts alone remaining, whilst below the saturation level, in a shallow excavation made in the corner of a small pond, a bed of hard Crag was met with containing actual aragonite shells, though in so advanced a stage of decomposition that it was impossible to secure a specimen. It is interesting to observe that where well-marked lines of flow occurred, even the calcite shells were entirely removed.

In the same connection we may quote from Mr. Sorby's address

a passage which has reference to the Portland Oolite. It will be noticed that Mr. Sorby's conjectures are borne out in detail by our experiments. The passage is as follows: "Where the deposit has taken place in a current, they (the aragonite shells) are more or less completely absent, probably because they had become tender by decomposition and were broken up before final deposition. Under similar circumstances the calcite shells have resisted complete disintegration and still show the original structure."

At Walton-on-the-Naze the uppermost beds of fossiliferous Red Crag contain very few calcite shells and immense numbers of aragonite shells. The latter are as a rule greatly decorticated and often quite pulverulent. The overlying bed formerly referred to as "Unproductive Sands" does not as a rule contain any shells, but thin lenticular patches of greatly decomposed fragments of shells occur, the species of which could sometimes, though rarely, be determined. This, and the circumstance that locally pipes of unproductive sand descend into the fossiliferous beds below, show conclusively that this was a case of decalcification. A prior observation by Mr. Whitaker (Q.J.G.S. vol. xxxiii.) led him to the same conclusion.

In a Coralline Crag-pit opposite Mr. Chaplin's farm-house on the road from Dullingham to Sudbourne, very loose sand containing only decomposed calcite shells can be seen to pass up into a loose sandy bed destitute of fossils.

Near Sudbourne Church a similar sand occurs, which can be recognised as decalcified crag, by the circumstance that a large percentage of the sand grains are coprolitic, a character which distinguishes the Red and Coralline Crag from all other deposits.

In the classical pit in Sudbourne Church Walks (Mrs. Rackham's), where the superposition of Red upon Coralline Crag can be observed, the Coralline Crag has suffered the removal of its aragonite shells, while the overlying Red Crag contains a profusion of organisms of aragonite constitution, a fact which appears to indicate that, previously to the deposition of the Red, the Coralline Crag had stood above the sea-level and had undergone submergence.

Part II.

As stated by Mr. Sorby, the true mineralogical character of any calcareous organism is best indicated by the specific gravity. This was determined by Mr. Sorby from the powdered substance. We were desirous, however, to ascertain if the destruction of the specimens could be avoided; and the following numbers from our determinations by the method of suspension show that in many cases at least it is not necessary to sacrifice the specimen. In the case of univalve shells, however, it is sometimes necessary to break into the whorls. Where a recent specimen has a thick epidermis, this must be removed by caustic soda.

The observations which follow were made in following out the indications obtained:—1. from the known inferior stability of aragonite fossils; 2. from the rule which appeared to hold with regard

to the translucency of calcite fossils and the opacity of those of aragonite.

Nature of Specimen.	Weight of Specimen.	Sp. gr.
Crystal of aragonite hexagonal (twin form)	37·3560 grams	2·933
Aragonite, fibrous variety	23·5111 ,,	2·857
Artemis lentiformis (fossil, opaque)	4·7490 ,,	2·840
Pectunculus glycimeris (recent)	3·9445 ,,	2·845
Calcite (cleavage rhombohedron)	3·0272 ,,	2·715
Pecten opercularis (fossil, translucent)	1·8711 ,,	2·70
Pecten opercularis (recent)	1·1116 ,,	2·70

Gasteropoda.

Scalaria, to which reference was made in the paper before quoted, proves to be calcite, as suggested from its translucency and mode of occurrence in the Coralline Crag. Its specific gravity is 2·685.

Murex tortuosus has a thick opaque inner layer, while the investment constituting the frills or varices is translucent. The specific gravity 2·85 indicates that the greater part of the shell is aragonite, as suggested by its appearance.

We are disposed to regard these features as valuable in the determination of the true affinities of the so-called *Purpura tetragona*, regarding which the late Dr. Jeffreys and Mr. Searles V. Wood jun., were at issue. *Purpura* as typified by *P. lapillus* has an extremely thin opaque layer, which does not reach the edge of the outer lip, and the specific gravity corresponds with that of calcite shells. *P. tetragona* on the other hand is opaque, with a translucent layer so insignificant in thickness that it is removed by attrition from all the prominences. The translucent layer is not visible within the outer lip.

The affinities of *P. tetragona* are therefore probably with *Murex arenaceus* rather than with *P. lapillus*.

Tectura testudinaria. Sp. gr. of recent specimen 2·834. In the fossil state it is opaque, with a translucent outer layer, hence we may conclude that, as in the case of *M. tortuosus*, the inner layer is aragonite and the outer calcite.

Fusus.

This genus furnishes evidence, which we consider to be conclusive, respecting the determination of the constitution of calcareous shells by their opacity or translucency in the fossil state.

Mr. Sorby stated in his address that the inner layer of *Fusus*, as typified by *F. antiquus*, is aragonite, the outer calcite, and in the paper by one of us already cited it was mentioned that the inner layer was opaque and the outer translucent, and several fossil species were instanced, which, being entirely opaque, were probably wholly aragonite. The sp. gr. of three species which have been determined by us shows them to be wholly aragonite. We give the sp. gr. of *F. antiquus* for comparison.

F. antiquus	sp. gr.	2·668 (very thin aragonite layer)
F. costifer	,,	2·88
F. pyriformis	,,	2·95
F. longævus	,,	2·89

The exceptionally high sp. gr. of *F. pyriformis* is no doubt to be accounted for by the fact that the specimen was impregnated with oxide of iron.

CEPHALOPODA.

Ammonites.—From the mode of occurrence of these shells, the circumstance that in porous beds casts only are preserved, and the similarity in appearance of the shells to those of *Nautilus* (determined by Mr. Sorby to be aragonite), we are justified in assigning them to the aragonite division.

The *Aptychi*, however, have the translucency characteristic of calcite, and they are found well preserved in beds such as the Chalk, in which the Ammonites are only represented by casts. The determination of the sp. gr. 2·70 shows them to be calcite.

Belemnites.—We find in Woodward's Manual of Conchology, p. 173, that according to the determination of Mr. Alex. Williams, the sp. gr. of the guard of *Belemnites puzosianus* is 2·674, and that of *Belemnitella mucronata* 2·677; they are therefore calcite, as their translucent appearance, familiar to all geologists, would lead one to suppose.

The phragmacone of *Belemnitella* is not known, and as no aragonite shells are preserved in the Upper Chalk, we were led to believe that the phragmacones of Belemnites would prove to be aragonite. Mr. Robert Etheridge kindly furnished us with a specimen in which the chambers were filled with translucent calcite, while the septa and the siphuncle which were preserved presented the usual chalky appearance of aragonite. The specific gravity was found to be 2·75, justifying the belief that a small quantity of aragonite was present, with the greater certainty that the appearance of the specimen shows it to be free from oxide of iron, and the mode of deposition of the calcite in the chambers, together with its high degree of translucency, furnish guarantees of its purity. A specimen of *B. minimus* from the Gault has the phragmacone preserved, and it presents the appearance characteristic of aragonite. It may be of interest here to note that the homologous structure of sepia has been determined by Sorby to be aragonite.

POLYPLACOPHORA.

Chiton (recent), sp. gr. 2·848, therefore aragonite.

HETEROPODA.

Dolabella (recent), sp. gr. 2·859, therefore aragonite.

LAMELLIBRANCHIATA.

Pecten opercularis (recent), sp. gr. 2·70, therefore calcite.

Pectunculus glycimeris (recent), sp. gr. 2·845, therefore aragonite.

Artemis lentiformis (fossil), sp. gr. 2·84, therefore aragonite.

Teredo Norvegica.—*Teredo* is regarded by Dr. Sorby as a typical calcite shell: but certain tubular fossils found by one of us in the Crag, and which have been regarded as *T. Norvegica*, have the opacity characteristic of aragonite; and upon this circumstance and peculiarities in its mode of occurrence the opinion was based that the

reference of the form to *Teredo* had been erroneous. In this view the late Dr. Gwyn Jeffreys concurred. The fossil has a sp. gr. of 2·9, and is therefore composed of aragonite. We offer no suggestion as to its affinities.

Hexacoralla.

All those corals examined by Mr. Sorby consisted entirely or almost entirely of aragonite.

Parasmilia centralis.—The circumstances of the preservation of this coral in the Upper Chalk induced us to examine it, when we found that it was translucent, and therefore probably calcite. This conclusion is confirmed by the sp. gr. 2·70.

Polyzoa.

Mr. Sorby observes that many Polyzoa have a specific gravity intermediate between those of calcite and aragonite, and suggests that they may be composed of a *mixture* of calcite and aragonite. Observations by one of us on Polyzoa show that these two substances, as indicated by the translucency and opacity, are not actually intermingled, but, as we have found to be invariably the case in other organisms, occur as two distinct layers, inasmuch as many genera, such as *Eschara*, have, when well preserved, an outer opaque and an inner translucent layer, the former being absent in deposits from which the aragonite shells have disappeared. Here the disposition of the layers is the reverse of what is found in the Mollusca, which always have the aragonite layer internal.

Foraminifera.

Mr. Sorby has ascertained that certain of these (genera not specified) are composed of calcite, but the facts we have accumulated regarding the group show that one great family, the Porcellanea, is similar in occurrence and behaviour to those structures characterized by the possession of aragonite tests. Moreover, the aspects of the tests, which have suggested the names *Vitrea* and *Porcellanea*, are as well shown in the fossil as in the recent state, and agree exactly with the aspect of calcite and aragonite shells respectively. Although we have not yet direct experimental proof that the *Porcellanea* consist of aragonite, yet it will be seen from what follows that they have been shown to be, relatively to the *Vitrea*, unstable towards the action of carbonated water.

The form called *Biloculina ringens* occurs along with aragonite shells in the Coralline Crag of Gedgrave, and is the most abundant Foraminifer in that deposit; but at Aldeburgh, Iken, Sudbourne Cross Roads (Mrs. Sewell's Pit), and the White Gates Pit, Sudbourne Park (in the Coralline Crag from which the aragonite shells have been removed), there is not a trace of it; while the *Polymorphina frondiformis*, comparatively rare at Gedgrave, is found here well preserved.

In Prof. King's "Monograph on the Permian Fossils" (Palæont. Soc. vol. ii.) it is stated that no Imperforata Foraminifera are known from any formation below the Trias; but the most striking evidence

of the instability of *Porcellanea* is furnished by the list of Chalk Foraminifera in Dixon's "Geology of Sussex," of which an analysis is subjoined.

CHALK FORAMINIFERA.

Miliola, sp. rare.	*Porcellanea.*
Lituolidæ, 4 spp.	*Arenacea.*
Lagenidæ, 49 spp.	*Vitrea.*
Polymorphinidæ, 4 spp. and vars.	,,
Buliminidæ, 13 spp.	,,
Textularidæ, 16 spp.	,,
Globigerina, 6 spp.	,,
Rotalina	,,

The significant fact appears from this that in a deposit from which all the aragonite shells have been removed, among 93 specimens of Foraminifera recorded, only one porcellanous form is included, and that presumably in so bad a state of preservation as to forbid specific determination. Judging from the analogy of recent Foraminiferal deposits *from all depths*, the Chalk should have contained originally a considerable proportion of porcellanous species. The chain of evidence was, however, less complete than in the case of larger structures, where casts or replacements have been observed. We therefore tried the action of a solution of carbonic acid on *Miliola* (porcellanous) and *Rotalia* (vitreous) in the fossil state, with the result that the porcellanous species was reduced to a condition in which it was disintegrated by a stream of water, whilst the vitreous species maintained its integrity, neither did it lose its translucency or compact structure. It may be added that the strength of structure of the porcellanous is at least equal to that of the vitreous species.

From experiment and observation we may therefore infer that *Porcellanea* are of inferior stability to *Vitrea* in presence of carbonated water, and consequently that their absence from a formation such as the Chalk does not warrant the assumption of their non-existence at the period of its deposition.

Note.—Subsequently to the reading of the paper our attention was drawn to a communication by Prof. Sollas (Proc. Roy. Soc. Dublin, vol. iv. new series, 1885), in which the author comments on the rarity of Imperforate Foraminifera in the older rocks. The specific gravities were determined in the Sondstadt solution. The values obtained for recent specimens were *Vitrea* 2·626 to 2·674, *Porcellanea* mostly 2·7, but ranging to 2·722. We also have succeeded in obtaining sufficient recent *Spiroloculina* for determination by the specific gravity bottle in a state of fine powder. Two experiments gave respectively 2·70 and 2·71. As we have not yet completed our examination of this group, and the percentage of animal matter has not yet been determined, we express no opinion regarding the mineralogical constitution of the tests, but content ourselves with pointing out that, as in the case of aragonite organisms, opacity in the fossil state accompanies instability towards carbonated water, both probably being related to the *structure* of the shell.

V.—On the Occurrence of Porphyritic Structure in Some Rocks of the Lizard District.[1]

By Howard Fox, of Falmouth, and Alex. Somervail, of Torquay.

BEING the fortunate possessors of Prof. Bonney's valuable papers[2] on the Lizard Serpentines and Schists in a pamphlet form, we examined the coast this spring somewhat minutely from Polurrian Cove on the west to the Blackhead on the east of the Lizard Point. We had tracings of the entire coast in our pockets, taken from the 25 inch Parish Maps, and owing to fine weather, and a favourable state of the coast, we were able to visit some of the less accessible rocks, and to trace some beds which at times are covered with seaweed and shingle or débris from the falling cliffs. Prof. Bonney's porphyritic diabase had been previously identified by one of us after a long search over the 18 acres of rocks and boulders exposed at Polpeor at low-water spring-tides. We made ourselves familiar with this rock, and were thereby enabled not only to trace it further, but to recognize a porphyritic structure in many dykes and intrusions along the coast, and also in the darker bands of Prof. Bonney's "Granulitic Group."

Commencing at Polurrian, the most westerly point, we will proceed eastward, noting the chief localities where the porphyritic structure may most readily be observed.

Vellan Head.—About 250 yards N.W. of the granitic vein marked on the Ordnance Map, near the base of the cliff and opposite an island, some narrow porphyritic dykes occur in the midst of bands of disintegrated serpentine, steatite, etc., and quartzose rock.

Good Gastol (?).—At the inner end of a little cove about 300 yards S.E. of Oliver's Refreshment Room at Kynance Cove there are some dykes with a few crystals of felspar scattered through their compact dark matrix.

Holestrow.—On the foreshore at the southern end of this land slip and a little N.W. of Pentreath Beach are several masses of banded crystalline rocks *in situ* resembling the "Granulitic Group." In these rocks may be discovered by careful search felspar crystals scattered through the matrix of the darker bands.

Pentreath Beach.—At the extreme north end of this beach a granitic vein runs up the cliff. Adjoining are some trap dykes also cutting the serpentine. About 100 yards south of this point a porphyritic dyke may be seen at low-water running in a N.W. and S.E. direction. This dyke is again found in a chine in the cliff in a line with its strike. At the south end of this beach occurs the junction of the serpentine with hornblende schist. About 100 yards south of this junction we find indications of porphyritic structure in the massive cliffs, here chiefly composed

[1] An Abstract of this paper was read before the British Association, Section C. (Geology), Manchester, September 1887.

[2] Quart. Journ. Geol. Soc. Nov. 1877, pp. 884-928, and Feb. 1883, pp. 1-24.

of micaceous schists. These indications continue for the next 300 yards, viz. to considerably south of Caerthillian, and on the foreshore are seen stones and boulders of typical porphyritic structure.

North Caerthillian.—The most readily accessible place where a typical porphyritic rock may be seen *in situ* is immediately N.E. of the headland which bounds Caerthillian on the north. This spot can be reached with ordinary care from the top of the cliff, which is lower here than on either side. A quartzo-felspathic rock is exposed close under the soil, and a few yards below it are several bands alternating of porphyritic and granulitic rock much faulted. The darker bands are thickly studded with small well-defined crystals of felspar, which on the weathered surface project beyond the matrix. These bands can be traced for 20 yards in a N.W. and S.E. direction, much twisted. They extend in a S.W. direction to high-water mark and down the cleft to the south.

South Caerthillian.—Some rocks apparently *in situ* on the foreshore 70 to 100 yards south of Caerthillian Cove show crystals of felspar in their soft micaceous matrix. The adjoining cliffs show a porphyritic structure in a more compact rock.

Pistil Ogo.—Rounding the Lizard Head, we can descend the cliff at this place, where we find a greenish porphyritic rock running N.W. and S.E., and 200 yards further east we reach the most southern point.

Polpeor.—When the shingle and seaweed have sufficiently left the coast, the porphyritic diabase discovered by Prof. Bonney can be traced running N W. and S.E. for 150 to 200 yards. It is exposed in the micaceous and hornblendic schists in an intricate manner, appearing again and again at and near the base of the cliff and on the foreshore both in Polpeor and the adjoining cove to the N.W. It can be traced in the mass of rock which at half-tide forms the eastern boundary of Polpeor beach, and through this on the foreshore still further east towards Polpeor Island. It appears again in Vellan Drang 200 yards S.W. of Polpeor Cove in the strike of the Pistil Ogo Beds.

Parn Voose (locally Penvose).—This cove directly north of the Balk Quarry is the place at which Prof. Bonney's "Granulitic Group" sets in, and continues with alternations of hornblende schist and serpentine to Kennack Beach. Here also the gabbros appear in mass, and here the porphyritic structure in the dark bands of this crystalline series may be seen to advantage. The foreshore is strewn with boulders recently fallen from the cliff, and the crystals of felspar in some of these are from one to two inches long and almost as broad. The same occurrence of crystals is seen in the cliffs, but not to such advantage as in the boulders.

Polbarrow.—Proceeding still eastward past Lean Water and Gothan Point or Whale Rock, we come to Polbarrow, and can trace porphyritic indications throughout this region.

Kildown.—East of Cadgwith we also find crystals and felspar in the dark bands of the granulitic group.

Caerleon.—Here Prof. Bonney's porphyritic dyke[1] is seen about 100 yards south of the Poltesco Serpentine Factory.

Passing Caerleon Cove, we climb up the hill by the Coast-guard path, cross the rocky slope above "Little Cove," and scramble down into the next small cove north of a projecting serpentine headland called in the Parish Map Polbream Point. Here we find rocks with large crystals of felspar, both *in situ* and in boulders scattered over the rocky foreshore for the next 300 yards northward.

Cavouga.—The Parish Map gives the name of Cavouga to the serpentine rocks running out to sea 100 yards north of Polbream Point, and as the rocks containing large crystals of felspar occur on each side of these serpentine rocks, it may be an appropriate name by which to designate this region.

There are two exposures of these large-crystalled porphyries *in situ* at the foot of the cliffs; the first about 90 yards S.W. of Cavouga Rocks, the second about 200 yards north of them, or say 600 yards N.E. of Poltesco Serpentine Factory. The first of these appears to cut the serpentine, and can be traced up the cliff, the darker bands containing both large and small crystals of felspar at various angles, and the associated lighter bands resembling the quartzo-felspathic bands of the "Granulitic Group." The second exposure north of Cavouga Rocks resembles three dykes cutting through the serpentine; but, as Colonel MacMahon suggests, it may be one dyke which by pressure has been doubled up on itself. Between and on either side of these two exposures the darker bands of this crystalline series of rocks show from time to time distinct crystals of felspar in the massive rocks as well as in those which appear to cut the serpentine as dykes. On the foreshore are many boulders so studded with crystals as to resemble mosaic, the crystals occasionally reaching a length of nearly six inches and a breadth of from two to three inches. One boulder had some of the crystals beautifully tinted with red.

Kennack.—In proceeding east to Kennack, we trace the crystals in the dark bands of the granulitic group, and on reaching the beach we find the porphyritic structure very marked in some isolated masses of the same group, one of which Prof. Sedgwick described as a "Greenstone porphyry."[2] North of these in a low cliff we trace a similar structure.

Green Saddle.—About 500 yards E.S.E. of the thatched shed at the extreme east of Kennack Beach there is another exposure of rock with large crystals of felspar resembling a dyke cutting the serpentine. The foreshore is here also strewn with boulders of porphyritic rock.

Summary.

The crystals of felspar are found to be most numerous in those rocks which lie in the closest proximity to the gabbro and serpentine;

[1] Quart. Journ. Geol. Soc. Nov. 1877, p. 900.
[2] Trans. Cambridge Phil. Soc. vol. i. p. 18.

they have their long axis at various angles, and are mostly small, except at Parn Voose, Cavouga, and Green Saddle. The felspathic and hornblendic lines often circle round the crystals.

Such is a brief statement of the bare facts of our observations in this particular direction. Without discussing any theory as to the true nature and origin of the whole of the schists, we think that the porphyritic structure, so prevalent in the dark bands of the "Granulitic Group," in many of the micaceous and other rocks, as also in the later intrusions cutting the serpentine, indicates an igneous origin for many rocks hitherto regarded as schists.

VI.—On the Principal Modifications of the Spirals in the Fossil Brachiopoda.

By the Rev. Norman Glass.

DR. DAVIDSON, assisted by the writer, gave a provisional sketch of the classification of the spiral-bearing Brachiopoda in the volume of the Palæontographical Society for 1883.[1] As Dr. Davidson then said, our design was "to assist those palæontologists who might feel inclined to continue the subject." The following notes have been written by me for the same end, and I think that if they are carefully read and compared with the figures in Dr. Davidson's Carboniferous, Devonian, and Silurian Supplements, they will give a tolerably clear idea to the student of a very complex and difficult subject. I have perhaps some claim to write upon this subject from the years of close and continuous investigation which I have devoted to it, and from the fact that I have discovered a large proportion of what is now known concerning the spirals and their connections.

In the "Geologist," 1858 (vol. i. pp. 457–473, folding plate xii.), Dr. Davidson gave figures and descriptions of all that was known up to that date concerning the spirals and their connections. The comparison between these figures and those given in his Carboniferous, Devonian, and Silurian Supplements in 1880 and 1882 is very remarkable as showing how recent have been the great majority of the discoveries in this interesting group. I have thought, therefore, that it might add to the interest of my notes if I gave in each case the date of the discovery and the name of the discoverer, that is, so far as these are known. Of course it will be understood that there are many genera and species which have the same internal characters as to the position of the spirals, their attachments to the hinge-plate,

[1] Anticipating a delay of fifteen months, owing to the retarded appearance of his Monograph in the Palæontographical Volume, the veteran author on the Brachiopoda, Dr. Davidson, published the result of his labours, in association with the Rev. Norman Glass, concerning the calcareous spirals of the Palæozoic Brachiopoda, in the Geological Magazine for 1881 (Decade II. Vol. VIII. pp. 1, 100, 145, and 289), illustrated by Plate V. and fourteen Woodcuts. It will be well for the reader to refer to these articles, as the figures therein given more fully elucidate the present paper, and the whole subject is treated in greater detail by Dr. Davidson; save and except the additional remarks made by Mr. Glass herein, which refer to discoveries of a later date than 1881.—Ed. Geol. Mag.

and their connections with each other, but only the first discovered example will be given of each distinct and peculiar form. The names and dates given in brackets refer in each case simply to the discovery of the calcareous spirals.

The Position of the Spirals in the Shell.

In the *Spiriferidæ* the spirals have their bases facing each other in the centre of the shell, but usually their apices have a more or less upward direction towards the posterior angle of the lateral margins of the shell. This upward direction is very marked in *Spirifera lineata*, var. *imbricata*. The spirals are sometimes directed backwards into the rostral cavity of the ventral valve as well as upwards, for example in *Cyrtina heteroclita*.

In all the other families or groups of the spiral-bearing Brachiopoda the spirals are always so disposed as that a transverse section taken through the greatest circumference of the shell would as nearly as possible pass through the apices of the two spirals and the centre of their respective bases. The spirals which are thus arranged in the shell have, so far as has been ascertained, six different positions in the various genera to which they belong.

Supposing that the dorsal or lesser valve in a specimen of *Athyris* has been removed, the spirals will then appear with their bases facing each other in the centre of the shell, and their apices directed towards the lateral margins of the shell. The five remaining positions of the spirals referred to might all be obtained by rotating the spirals simultaneously each on its own axis—that is, its perpendicular axis, from the posterior to the anterior border of the spiral. (Of course this could not be done in the specimen itself, but the motion might be illustrated by two cones cut out in wood.) Thus, in the case of *Athyris* as described above, if the two spirals were rotated simultaneously outwards each on its own perpendicular axis, that is, the right-hand spiral to the right and the left-hand spiral to the left, the spirals would soon assume the position in the shell and towards each other of the genus *Dayia*, Dav. (Glass, 1880), in which the apices of the spirals face the middle of the lateral portions of the ventral valve. Continuing the rotation *Thecospira* (Zugmayer, 1880) is reached, in which the apices of the spirals face the bottom of the ventral valve. Again continuing the rotation we have successively *Glassia*, Davidson, 1881, in which the apices of the spirals face each other in the centre of the shell, *Zygospira*, Hall (Whitfield, 1862), in which the apices of the spirals are directed obliquely into the cavity of the dorsal valve, and *Atrypa*, in which the apices of the spirals face the bottom of the dorsal valve. And a still further rotation would bring the apices of the spirals to their first position as in *Athyris*.

The Attachments of the Spirals to the Hinge-plate of the Dorsal Valve.

There is not much variety here. In the *Spiriferidæ* the attachments are straight. In the *Nucleospiridæ* and *Athyridæ*, and in

Hindella, belonging to the *Anazygidæ*, the primary lamellæ shortly after attachment to the hinge-plate are bent backwards towards the ventral valve, each lamella forming an acute angle with the commencement of the first convolution of the spiral (this attachment was discovered by Davidson in 1858). In *Nucleospira*, Hall, and *Athyris*, M'Coy (Glass, 1882), this angle is bent or curved under like a beak. In some American species of *Athyris*, M'Coy (Whitfield, 1859), the angle is not acute, but more open and loop-like. In *Atrypidæ* and *Anazygidæ* the primary lamellæ shortly after attachment to the hinge-plate are bent outwards towards the lateral margins of the shell.

The Loop, or the Connections of the Spirals with each other.

In the *Spiriferidæ* the principal character is the straight attachment of the spirals to the hinge-plate. In *Spirifera* (Davidson, 1858) the loop is imperfect, consisting of two internal processes, arising from the primary lamellæ, and directed downwards between the spirals, but not uniting. In *Cyrtina*, Dav. (Glass, 1882), these processes unite at an acute angle. In *Spiriferina*, D'Orb. (Davidson, 1851), the loop consists of a straight or curved horizontal band almost on a level with the dorsal surface of the spirals.

In the *Atrypidæ* the principal character is the position of the loop exterior to and above the spirals. The loop is directed downwards, and is simple and rounded (Whitfield says that in some examples of *Atrypa* the loop is acutely angular—this had never been observed, however, by Dr. Davidson or myself). In *Atrypa*, M'Coy (Whitfield, 1866), the loop is small, in *Zygospira*, Hall (Whitfield, 1862), it is much wider, and lower down, and curves upwards towards the hinge.

In the *Anazygidæ* the principal character is the position of the loop rising from the bottom of the spirals. In *Anazyga* (Glass, 1882) the loop is simple and rounded, and exterior to the spirals. In *Hindella*, Dav. (Glass, 1882), the loop is simple and rounded, with a short spinous extremity, and interior to the spirals. In *Dayia*, Dav. (Glass, 1880), the loop is simple and angular, with a short spinous extremity, and it is placed between the primary lamellæ on the dorsal side of the spirals.

In the *Nucleospiridæ* the principal character is the presence of a simple loop, more or less angular, between and near the centre of the spirals, and directed almost horizontally from the dorsal to the ventral side of the spirals—for example, *Nucleospira*, Hall (Whitfield, 1859).

In the *Athyridæ* the principal character is the presence of an internal loop more complex than that of the *Nucleospiridæ*, and extending upwards from the centre of the spirals. The loop of the *Athyridæ* is really an extension in an upward direction of the simple loop of the *Nucleospiridæ*. In *Bifida*, Dav. (Glass, 1882), there is a small bifurcation at the end of the simple loop. In *Whitfieldia*, Dav. (Glass, 1881), the loop is extended further upwards than in *Bifida* by a rather long single process, which occurs between the simple loop

and the bifurcation. In *Meristella*, Hall (Whitfield, 1860), each side of the bifurcation at the end of the simple loop curves round upon itself so as to form a ring. This loop, which thus contains two rings, occurs also in *Merista*. In *Athyris*, M'Coy (Davidson, 1858), there is a roof-like expansion at the end of the simple loop, from the top of which two accessory lamellæ curve upwards and backwards to the inside of the primary lamellæ, and are continued downwards to the centre of the spirals on the dorsal side. In *Kayseria*, Dav. (Glass, 1882), at the end of the simple loop there is a single rounded process, and at the end of this process the loop bifurcates in an upward direction, as in *Athyris*. The accessory lamellæ, however, do not terminate as in *Athyris*, but are continued between the main coils to the end of the spirals.

Thus there are fourteen forms of loop known, most of which have been recently discovered.

Dr. Waagen describes the interior of the genus *Eumetria*. He says, "The primary lamellæ are very strange in their development. They show broad wing-like expansions at their origin, which are sometimes very strongly developed." This "very strange" development had been previously worked out by me, and figured by Davidson in 1881 as existing in *Athyris plano-sulcata*,[1] in which the primary lamellæ near their origin increase in width—the increased width extending downwards nearly to the centre of the spirals on the dorsal side. Dr. Waagen gives a description of the loop of *Eumetria*, and it seems to be similar to the simple loop of the *Nucleospiridæ*, with the exception that the loop commences nearer to the origin of the primary lamellæ, and has a downward direction between the spirals. Supposing this to be correct, the loop of *Eumetria* forms an addition to the number of loops previously worked out.

Davidson gives two figures of the loop of *Uncites*[2] in his Devonian Supplement, 1882. From these figures the loop would seem to be simple and transverse as in *Spiriferina*, with the exception that there is a thickening at the centre of the loop, which on the upper side amounts to a short spinous projection. The attachments to the hinge-plate are straight, as in the *Spiriferidæ*.

With the exception of the spirals in *Thecospira*, and the loops in *Spiriferina*, *Eumetria*, and *Uncites*, all the particulars given above have been carefully verified by my own preparations.

P.S.—I have made no reference in the above article to the eminent Palæontologists by whom the respective genera were determined and described. The discoveries of Mr. Whitfield were described by Prof. Hall, of Albany, U.S. My own were described by Dr. Davidson, whose recognition of any assistance I may have rendered him in his great work was always most generously made. (As see Geol. Mag. 1881, *loc. cit.*)

[1] See Geol. Mag. 1881, Dec. II. Vol. VIII. p. 5, Figs. 2 and 3.
[2] See Geol. Mag. 1881, Dec. II. Vol. VIII. p. 153, Figs. 20 and 21.

VII.—Notes on Carboniferous Selachii.[1]

By Dr. R. H. Traquair, F.R.S., F.G.S.

The *Cladodontidæ*.

The teeth known as *Cladodus* (type *C. mirabilis*, Ag.) have a flattened, transversely elongated, sub-elliptical or reniform base, the anterior margin being straighter than the posterior and often slightly excavated in the middle. Anteriorly the base is thick, and generally shows a groove separating the truly basal from the coronal portion, while the posterior margin is thin owing to the downward and backward slope of the upper surface. From this upper surface anteriorly spring a number of cones or denticles, of which the median is the longest; it is flanked by lateral denticles, of which an outer one on each side is longer than those intermediate. The larger denticles, at least, are flattened antero-posteriorly and have lateral cutting margins.

There are two exceedingly well-marked species of common occurrence in the British and Irish Carboniferous Limestone, namely, *C. mirabilis*, Ag., and *C. striatus*, Ag. *C. marginatus*, Ag., I also believe to be a good species, as well as *C. Milleri*, Ag. On *C. acutus*, Ag., *conicus*, Ag., *basalis*, Ag., *Hibberti*, Ag., and *parvus*, Ag., I offer no opinion, not having seen the types; but as to the new species added by Mr. J. W. Davis in his large work on the fossil fishes of the Carboniferous Limestone series of Great Britain[2] there is scarcely one which will stand the test of careful comparison with the common species described by Agassiz. *C. Hornei*, Dav., *C. elongatus*, Dav., and *C. curtus*, Dav., are in my opinion simply synonyms of *C. striatus*, Ag.,—*C. mucronatus*, Dav., and *destructor*, Davis, of *C. mirabilis*, Ag. It is rather difficult to give any opinion upon *C. curvus*, Davis.

In the Edinburgh Museum, and in the Collection of the Geological Survey of Scotland, there are a few teeth of what is evidently a new species of *Cladodus*, from the Lower Carboniferous rocks of Eskdale in Dumfriesshire, though I refrain on the present occasion from giving it a name. In these teeth the surface of the cones is perfectly smooth and glossy, and in the absence of striations they approach *C. van Hornei* and *prenuntius* of St. John and Worthen. The thought has struck me, is it possible that this undoubted *Cladodus* may represent the dentition of *Ctenacanthus costellatus*, the unique specimen of which, with the spines *in situ*, occurred in the same beds? It will be recollected that the only tooth visible in the specimen of *Ctenacanthus costellatus* was an imperfect one, but its one visible cusp was smooth. If there is any connection here, the specimen of *Ct. costellatus* must have been a young individual, as these teeth indicate a fish of much larger size.

This brings up once more the question of the correlation of *Cladodus* and *Ctenacanthus*, a question which I must admit is still involved in great obscurity. When I wrote my description of

[1] Read before the Royal Physical Society of Edinburgh, 18th January, 1888.
[2] Trans. Roy. Dub. Soc. 1883.

Ctenacanthus costellatus,[1] I was inclined to believe that *Ctenacanthus* and *Cladodus* represented the spines and teeth of the same genus, and that the genus itself was *Hybodont*.

Mr. Garman, however, in his paper on *Chlamydoselachus* disputes that view, and claims that remarkable recent shark which has only one dorsal fin and no spines at all—a form placed by Dr. Günther in the family Notidanidæ—to be the modern representative of the ancient Cladodonts. It is perfectly true that the small teeth towards the angles of the mouth in *Chlamydoselachus* when seen from the front strongly resemble those of *Cladodus*, yet this resemblance is not very apparent in those which cover the greater part of the jaws, while the bases of the teeth are to my eye strikingly dissimilar. I cannot therefore, without further evidence, accept Mr. Garman's very confident assertion that *Chlamydoselachus* is a Cladodont, leading as it does to the inference that *Cladodus* had no dorsal spines. That *Cladodus* at all events is not quite so close to *Chlamydoselachus* as Mr. Garman believes is, I think, fully shown by a remarkable specimen from the Carboniferous Limestone of East Kilbride, Lanarkshire, which has been lent to me for description by its possessor, Mr. James Neilson, of Glasgow.[2] This specimen was recovered from the quarry in separate pieces by the late Mr. A. Patton, who, I understand, did not feel sure that they all belonged to the same specimen. However, the fragments were pieced together by Mr. Neilson, and after a most careful scrutiny of the whole, I have come to the conclusion that the fragments do belong to the same specimen and are rightly arranged. We have first a head, compressed from above downwards, whose jaws are crowded with truly cladodont teeth of the type of *C. mirabilis*, though apparently belonging to a hitherto undescribed species. This is followed by a mass of crushed and inextricably confused cartilages representing the branchial apparatus, and then come two scapulo-coracoids, each with a pectoral fin attached. The fin of the right side is the better preserved, and shows first a number of elongated radial pieces whose bases, separated from the rest by joints, are attached directly to the shoulder-girdle and evidently represent the propterygium and metapterygium of ordinary Selachii. Behind these is an oblong metapterygium bearing radials preaxially, whose anterior portion seems to have absorbed the bases of one or two adjacent radials, but whose posterior extremity is continued backwards as a long narrow segmented stem consisting of nine rectangular joints, and reminding one at first sight of a vertebral column! This part in both fins is cut off by the edge of the stone, so that its actual length and number of segments are not seen. Some small radials are seen attached to the preaxial side of the first two segments,—none on the others, or on the postaxial side of the stem.

The interest of this specimen is extreme, as it is at least capable of bearing the interpretation that we have here a veritable uniserial

[1] Geol. Mag. Jan. 1884, pp. 3–8.

[2] As I have promised to lay a detailed description of this specimen before the Geological Society of Glasgow, I can only make a few general remarks upon it in the present instance.

archipterygium, intermediate between the truly biserial one of *Xenacanthus* and the pectoral fins of ordinary sharks. If this interpretation is correct, then, along with *Xenacanthus*, this specimen is a witness against the lateral fold theory of the paired fins, at present so popular with anatomists and embryologists. Into that question I shall enter on another occasion, meanwhile so much is clear, that if we have before us the pectoral fin of *Cladodus*, and I do not doubt that we have, the affinity between that genus and *Chlamydoselachus* is not quite so close as Mr. Garman maintains, seeing that in his fish the pectoral fin shows the ordinary arrangement of basal pieces, though the metapterygium has two segments.

What then of the *Ctenacanthus* theory? No spine is seen in connection with the East Kilbride *Cladodus*, but as the body is absent, spines may have been borne by the fish when complete. Again, in the Eskdale *Ctenacanthus* the form and structure of the pectoral fin are not shown, and though I interpreted its one imperfect tooth as "Cladodont," I am willing to leave that an open question. It may be *hybodont*, and the hybodont form with its vertically compressed base must not be confounded with the cladodont type with its base horizontally flattened and irregularly elliptical or reniform. And in one of the instances which have been advanced to prove the connection of *Cladodus* with *Ctenacanthus*, a mistake has certainly been made. So far as I have seen them, the teeth which are found associated with the Coal-Measure *Ctenacanthus hybodoides*, Eg., do not belong to *Cladodus mirabilis*, Ag., as has been asserted, but are allied to *Hybodus* in their narrow, compressed non-expanded bases. Mr. J. W. Barkas long ago expressed his opinion that "most of these so-called *Cladodi* are in reality *Hybodi*" (M. Rev. Dent. Surgery, February, 1874), though he seems to think that the great difference between *Cladodus* and *Hybodus* lies in the former having the outermost denticles larger than the intermediate ones, and consequently admits some of these Coal-measure specimens to the genus *Cladodus*.

Ctenacanthus hybodoides has therefore nothing to do with *Cladodus*, and as regards the other species, I rather think that, if we knew the creatures to which they belonged, they would turn out to represent several types, possibly very different from each other. But of this I have now no doubt, namely, that the Cladodontidæ, whether they had spines or not, or whatever the shape of their spines if they had any, constitute a very different family from the Hybodontidæ—while the latter on the other hand were closely allied to the Cestraciontidæ. For if *Tristychius* be a Hybodont, we have now some clue to the structure of an ancient representative of the family.

Tristychius, Agassiz.

A specimen of *Tristychius*, from Eskdale, allied to, if not identical with Agassiz's *T. arcuatus*, shows the greater part of the body with the head, one pectoral fin and two dorsal fins. Each of the dorsal fins has a spine in front. The pectoral shows two large basal pieces which I interpret as mesopterygium and metapterygium, the propterygium being either small or fused with the mesopterygium as in

Cestracion, while there is no trace of the segmented prolongation of the metapterygium which we saw in the E. Kilbride *Cladodus*.

This interesting specimen is fatal to Mr. T. Stock's idea that the spines in this genus were *paired*,[1] as well as to its location among the Chimæroids as maintained by Prof. Hasse.[2] That it is a Hybodont cannot, in my opinion, be doubted.

Orodontidæ, De Koninck.

If the Mesozoic genus *Acrodus* be a Hybodont,—and its spines are generically indistinguishable from those of *Hybodus*,—it is difficult to draw any line between the Hybodontidæ and Orodontidæ.

One of the genera which De Koninck and Mr. Davis place in this family must, however go, namely, *Lophodus* of Romanowski. Romanowski separated from Agassiz's *Helodus* such forms as *didymus*, *lævissimus*, *mammillaris*, as having one or more prominent elevations on the crown, and a well-developed compressed and vertically striated root, while he considered *H. planus*, which has no such root and no special elevation on its crown, to represent the old genus. Unfortunately both "*Helodus*" *planus* and "*Lophodus*" *didymus* belong to the mouth of the same fish, and that fish is *Psephodus magnus*! Moreover, as I have once remarked, if the old genus *Helodus* was to be divided, surely the characters of the type-species, *H. simplex* of the Coal-measures, ought first to be ascertained and duly considered. Now a fine series of specimens of *Helodus simplex*, Ag., in the collection of Mr. John Ward, F.G.S., Longton, clearly shows that the teeth in this species have the form of "*Lophodus*," that the entire dentition consisted of teeth generally similar in shape, and that the dorsal fins were armed with spines resembling those of *Pleurodus*.

Whatever be the nature of the teeth which Mr. J. W. Davis retains in, and adds to *Helodus*, there can be no doubt that *H. simplex* must remain the type of Agassiz's genus, in which also *Chomatodus cinctus*, Ag., ought to be placed, as already indicated both by McCoy and Davis.

Cochliodontidæ.

The closeness of the alliance between the Cochliodontidæ and Orodontidæ is shown by the fact that the anterior teeth of *Psephodus* and *Cochliodus* are generically indistinguishable from those of *Helodus*.

As seen in *Psephodus*, which is one of the least specialized of the Cochliodontidæ, the posterior teeth lose their deep roots, become flattened, and tend to fuse together into broad inrolled plates. I have a specimen of the broad tooth plate of *Psephodus magnus*, Ag., which by a groove is divided longitudinally into two portions, which pretty closely represent not uncommon forms of *Helodus planus*. The grooves on *Pœcilodus*, *Deltodus*, etc., also to my mind represent the morphological origin of those plates from the fusion of smaller

[1] Ann. and Mag. Nat. Hist. (5), xii. 1883, p. 188.
[2] Natürliches System der Elasmobranchier.

and narrower separate teeth. *Pleurodus* is a well-known form, in which each plate is evidently due to the union, back to front, of a row of helodont teeth whose lateral extremities still tend to project free on each side.

That the Cochliodonts all possessed dorsal spines seems highly probable. Those of *Pleurodus* have been described by Hancock and Atthey.

Petalodontidæ.

If we take *Ctenoptychius apicalis*, Ag., as the type of its genus, I must own that I fail to see any valid reason for separating *Ctenopetalus* from it, and even *Petalodus* is scarcely entitled to distinction. *Harpacodus* differs in having only one fold or plait at the junction of the crown and root, and it is in this genus that Mr. J. W. Davis proposes to include *Ctenoptychius pectinatus* of Agassiz. But *Ctenoptychius pectinatus* is not provided with any "fold" of enamel below the crown comparable to those in *Ct. apicalis*, or to the single one in *Harpacodus*, while its root differs very considerably in shape, being divided below into a number of small rootlets, somewhat after the manner of *Polyrhizodus*. A new genus is therefore necessary for it, for which I propose the name *Callopristodus*.

Oracanthus.

Some time ago Mr. R. Craig, of Langsyde, Beith, lent me a small spine from the shale above the 9-inch coal at Broadstone, Ayrshire (Carboniferous Limestone series), which is apparently undescribed. It is small, flattened and broadly triangular, the anterior margin being 1 inch in length, the posterior $1\frac{3}{8}$, the base $\frac{3}{4}$ inch in breadth. The apex ends in a sharp spike, and just below this on the posterior margin are two others directed backwards. Externally the surface is ornamented with distinct furrows running parallel to the anterior and posterior margins, consequently tending to radiate from the apex towards the base, and giving the surface a feebly ribbed appearance. On these ribs are small tubercles, irregularly placed towards the apex, then becoming arranged in lines which proceed obliquely, or with a slight sigmoid curvature, across the surface from behind downwards and forwards. I have seen other specimens of the same spine from the Carboniferous Limestone "Bone-bed" at Abden, Fifeshire, collected by Messrs. W. Anderson and W. Tait Kinnear, which show that the walls were thin and the spine consequently extremely hollow. In these specimens the external ribbing is also feeble, and the tubercles more thickly placed.

In their general configuration and in the nature of their surface ornament, the resemblance of this spine to *Oracanthus* is obvious, although the posterior area is not so sharply defined, and though neither of the sides is notched or sinuated on the lower margin as is, so far as my observation goes, usually the case in the genus mentioned. It has, perhaps, still thinner walls than in the typical *Oracanthi*, and might on that account be referred to St. John and Worthen's genus *Puigeacanthus*; but the generic distinction of this from *Oracanthus* is doubtful. No *Oracanthus* has hitherto been described with spikelets

at the apex, but as the apices are more or less worn, a ready explanation of their absence is obtained. I therefore designate this spine *Oracanthus armigerus*, with the remark that if it be not a true *Oracanthus*, it is an excessively closely allied form.

Mr. Davis recognizes that the spines of *Oracanthus* existed in pairs, and are not bilaterally symmetrical, having one side larger than the other; but when he refers them to the "posterior termination" of the body, hints at removing the genus to the "Placodermic Ganoids," and figures a whole series of really undeterminable fragments as bones of the head of this supposed Placoderm, we can hardly follow him. I have carefully gone over all the specimens in the British Museum which he has figured as "upper jaw," "central bone of cranium," etc., and can find no evidence for such determinations. I have also examined microscopic sections of *Oracanthus*, and find that they consist of Selachian dentine. And we may also appeal to the obvious resemblance, which the spines of *Oracanthus* bear to the thin-walled triangular appendages often found associated with *Gyracanthus*, which, though not "carpal bones," as Messrs. Hancock and Atthey imagined, are unquestionably Selachian in their nature.

The writer of a review of Mr. Davis's work, which appeared in the Geological Magazine for November, 1883, does not believe that the *Oracanthi* formed the posterior extremity of the body of a Placodermic Ganoid, but that "it seems probable that they may have occupied a lateral position on the head of these old Elasmobranch fishes." And if I am right in my determination of *Oracanthus armigerus*, sufficient corroboration of this view has now turned up.

In the Museum of Science and Art, Edinburgh, there is a specimen from the Eskdale beds, showing the head of a small Selachian, crushed vertically, along with part of the body, the latter being, however, bady preserved. In the head are broken remains of several large flattened-convex tooth-plates, extremely Cochliodont in aspect, but too imperfect for identification with any known genus or species. But the great point of interest is that each postero-lateral angle of the head projects in a pointed process like the corner of a *Cephalaspis* buckler, and that process is—the spine which I have described as *Oracanthus armigerus*.

I think there can be no further doubt that the position of the *Oracanthus* spines is on the head of a Selachian, and not on the tail of a Placodermic Ganoid.

Addendum to *Cladodontidæ*.

I have long been of opinion that the teeth from Borough Lee, which I described as *Cladodus bicuspidatus*, and which never show more than two cones, a large one and one small lateral one, which is absent in some specimens, ought to be included in a new genus distinct from *Cladodus*. I therefore propose for this form the name *Dicentrodus*, and venture to express an opinion that it will turn out to be more allied to *Diplodus* than to *Cladodus*.

NOTICES OF MEMOIRS.

W. P. Jervis on Earthquakes.

IL CAV. W. P. JERVIS, F.G.S., Keeper of the Royal Industrial Museum of Italy, has published his Lecture to the Philotechnic Society, Turin, on the nature and causes of Earthquakes, with especial reference to that of February last at and near Mentone. This is a careful study of the earthquake of 1887 in North-western Italy and the neighbouring parts of France and Switzerland, establishing certain facts and advancing some possibly new hypotheses. An earthquake-area being regarded as that in which the shocks have sufficient force to be sensible to man, this earthquake had no connection with any volcanic action, and the movements were not propagated to the volcanic region of Central and Southern Italy. An outward external area, including the parts where the seismic disturbance was manifested by very delicate instruments and magnetized bars, would, however, bring us nearer to the region of extinct volcanoes in Central Italy.

After a close examination of the disturbance of springs and fountains, caused by the sliding or derangement of strata close to the surface, the result arrived at was that Mont Mercantour in the Maritime Alps, west of the Col di Tenda, was the centre of seismic action. That mountain and others associated with it seem to have been the foci of an elliptical, but nearly circular, area of shocks, with its greater axis of about 485 kilometres. The length of the axes of the outer area of shocks perceptible only by seismic or other instruments cannot be determined, the movements depending on the nature of the rocks; probably they were twice the length of the other axes. The summit of the Maritime Alps, from a short distance N.W. of the Mercantour to the junction of the Alps and Apennines above Savona, seems to have divided the earthquake-area. That part towards the Mediterranean and the bed of the sea itself were subject as well to vorticose as to undulatory and subsultory shocks. The lateral boundaries were defined by slight fissures (from one to two or three millimetres wide) in the rocks or soil, in a direction perpendicular to the Maritime Alps, from near the Mercantour to the vicinity of Mentone, and from the mountains to near Savona. The vorticose action was most curious, especially near Mentone, where crosses and upper stones or statuettes of marble were turned round 30° or 45° in the Protestant cemetery. Elsewhere only undulatory and subsultory shocks were apparent. A table of places affected, duration of shocks, and geological nature of the ground is given. Some of the physiological effects before and during the earthquake are noticed, also the hearing of strange sounds in the stillness of the night, as if at a great depth underground.

The slow changes of level along the coast from Marseilles to

Genoa,—the sinking of Roman buildings below the sea-level at the coast-line near the former mouth of the Rhone,—and the fact of stone-boring Molluscs being found many metres above the sea-level in other parts—led Issel to say that this coast-line is subject to slow upheavals and depressions; and these Mr. Jervis believes to be due to the district being the area of repeated earthquakes similar to that of last spring. But as the earthquakes seem to be due to the descent or sinking of mountain-masses towards the centre of the globe, it would seem that they could not be repeated without the gradual lowering of the mountains. Mr. Jervis, however, proposes the hypothesis that there is an extra-mundane cause of upheaval of certain mountain-groups. Referring to Flammarion as being probably correct on the whole, though very poetic and too much of a scenic artist to follow details patiently, Mr. Jervis proceeds with the idea that the sun and moon, in certain positions, may be able to attract a given mountain-mass very gradually, and to an exceedingly small extent,—such process being repeated again and again, each time causing a still further elevation of insensible height. In time, unstable equilibrium having been produced (especially at given moments following the transient recurrences of celestial attraction), terrestrial gravitation interferes, and the upheaved masses settle down, in some instances with rupture of the strata. Thus there are two phases of the disturbance;—first, a gentle and imperceptible upheaval, so gradual as to be unappreciable by our senses, and never yet established, except on a coast-line where the sea-level gives a fixed point of comparison. This might, however, be as fully proved inland, were the heights of fixed objects on mountains (such as the summit of a building, a signal stone, etc.) determined with mathematical precision, instead of the ever-varying mountain-top (as Mont Blanc) being taken, which may be worn down one to twenty feet in a century by frost and rain, and possibly be again upheaved from time to time so as to restore the geographical relief.

The earthquake, as it is called, would then be the phenomena caused by the influence of terrestrial gravitation,—the fall by which stable equilibrium is secured. In the author's opinion the elevatory process by far exceeds that of depression, allowing full play for the ever-active erosion, by which the Alps, for instance, may have been worn down even hundreds of feet in historic times. Are not earthquakes, then, absolutely necessary for restoring in some parts of the globe the equilibrium of certain forces and agents, as electricity? Do they not help to maintain the balance between the heights of mountains and the depths of seas?

The defective method of buildings, especially with vaults, allow of much of the disasters in earthquake-areas, and the author points out some practical technical precautions and the building-materials most fit for use in these places.

REVIEWS.

I.—The Ancestry of our Animals.

Les Ancêtres de nos Animaux dans les Temps Géologiques. By Albert Gaudry. 12mo. (Paris, 1888.)

IN this fascinating little volume of 296 pages, illustrated by a frontispiece and 48 woodcuts, of which several occupy an entire page, and are printed as plates, we are glad to welcome another of Prof. Gaudry's valuable and interesting contributions to the history of Fossil Mammalia.

The first chapter is a brief *résumé* of some of the more important steps in the progress of Palæontology, with a list of names of many famous workers in various branches. In the second we have an interesting discussion on the importance of the degree of evolution of the contained fossil Vertebrates in regard to the determination of the age of strata in different parts of the globe; in which is given a valuable table of the date of appearance of some of the more important groups of Vertebrates. Great weight is here attached by the author to the degree of specialization of the various genera of Selenodont Artiodactylia, as indicative of the relative age of the beds in which they occur: and illustrations of the doctrine of migration and colonization are given from the Mesozoic Mollusca. With the third chapter we enter on the proper subject of the volume—or the evolution of the Tertiary Mammalia; and here we find a large number of excellent illustrations of the chief types of dental and pedal structure, reproduced from the author's larger work on the same subject. This subject in the two succeeding chapters is further specially illustrated by the history of the fossil Mammals of Pikermi in Attica, and of Mont Lebéron in Vaucluse, which have been rendered classic by the author's earlier monographs; and some very interesting suggestions are made as to the influence which the fossil bones of the former area may have exerted on the mythologies and metamorphoses of the Greek and Roman classic writers.

The last two chapters are devoted more especially to the Palæontology of the Paris Museum; the seventh containing a review of the works of the author's predecessors in the chair of Palæontology. Excellent figures are given in the eighth chapter of some of the more important skeletons of Mammals which adorn the Mammalian Gallery, among which we may especially notice *Mastodon angustidens*, *Glyptodon typus*, *Palæotherium magnum*, and *Scelidotherium leptocephalum*.

We may conclude our brief notice of this volume, which we can heartily commend to all our readers—whether they be palæontologists or not—by some extracts from the end of the sixth chapter which are well worth the attention of those who are flooding our literature with the names of legions of so-called new species and genera.

M. Gaudry observes, "We must acknowledge that although the old

system of making a special name for the slightest variation is convenient, yet in distinguishing varieties from species palæontologists are exposed to many errors. In the living world, when the descendants from a single type present differences, which do not prevent the production of fertile offspring with the parent form, they are considered merely as varieties of the same species; but when these differences are such as to prevent the production of fertile offspring, they are regarded as indicating a different species. In palæontology not only are we unable to avail ourselves of this criterion, but it is difficult to guide ourselves by the analogies offered by existing animals, since there is an extreme inequality in the external characters separating varieties and species; as, for example, the varieties of the Dog differ more from one another than does the Ass from the Horse.

"This shows that we can only approximate among fossil forms to the degree of difference indicating a variety or a species. But, in order to come as near as possible to the truth, we should adopt the following plan:—viz. that when the differences separating fossil animals are of no importance from an evolutionary point of view, we may be permitted to regard such animals as mere varieties of a single species; that is to say, that they were all probably capable of producing fertile offspring among themselves."

Numerous examples are then cited of differences which may be regarded respectively as varietal and specific; the different proportions of the limb-bones of the Pikermi Hipparions being given as an instance of the former, while the three digits of the European *H. gracile* as contrasted with the single one of the Indian *H. sivalensis* are instanced as good specific characters.

In conclusion it is observed, "That whatever may be the difficulty in marking the distinction between fossil species and varieties, I consider this distinction as worthy the attention of naturalists. The history of past forms reveals, indeed, a succession of undefinable differences (*nuancés indefiniés*), which the Divine Wisdom can coördinate, but to desire to mark each of which by a special name is to only prepare lists without end, in which human weakness must lose itself!"

We cordially agree with these concluding remarks, and have no doubt that the author would extend them to embrace genera and the larger groups. The time has, indeed, come when we ought to accentuate the resemblances rather than the differences which we find among allied fossil forms; and to recognize that both in the case of specific and generic names it is advisable to use them in a much wider and less defined sense than we are accustomed to do when our study is restricted to the comparatively small fauna of the present day. R. L.

II.—Den nord-norske fjeldbygning. Af Karl Pettersen. Separataftryk af Tromsoe Museums Årshefter X. Tromsoe, 1887. 8vo. pp. 174, taf. i—iii.

THE author has been engaged since 1865 in working out the geological structure of the mountain district of North Norway,

and he now proposes to give in a connected form the results of his researches. This first part treats more particularly of the oldest series of the Archæan rocks, which is developed throughout the island bordering the coast, from Lofoten to the North Cape, and on the deeply indented coast-line of the mainland, and again makes its appearance in the interior of the country near the border-line between Norway and Finnish and Swedish Lapland. The rocks of the littoral or western series are named by the author *gneiss-granite*, whilst those of the Eastern are termed the *inland granite*. Between these series, which have a generally south-west to north-east direction, there is a belt of newer crystalline schists about 100 kilomètres (62 miles) in width, which the author believes to be deposited in a basin-shaped depression of the older rocks.

The gneiss-granite series consists of beds of gneiss intermingled with granite, but the granite presents no evidence of having been subsequently intruded into the gniess; it is of the same character as the gneiss, and there is a gradual transition from the one into the other. There are also frequent beds of pure quartz interdeposited in the gneiss-granite series. The author believes that all these rocks are of sedimentary origin, and that the materials of the gneiss have been derived from older granitoid rocks, which could not have been situated in the Scandinavian Peninsula or to the east of it, but probably existed in the area now occupied by the North Atlantic Ocean. From this supposed ancient continent the author believes that the Laurentian gneiss of North America was also derived, as well as those newer crystalline schists which fill up the basin formed by the gneiss-granite series in the Scandinavian Peninsula. These schists reach a thickness of 1000 mètres, they are quite unfossiliferous, but they are believed to belong to the Cambrian or lowest Silurian epoch.

The author gives an orographical review of the region and detailed descriptions of the geological structure of the different islands, as well as vertical sections in the accompanying plates. G. J. H.

REPORTS AND PROCEEDINGS.

Geological Society of London.

I.—December 21, 1887.—Prof. J. W. Judd, F.R.S., President, in the Chair.

The President announced that the Fourth Meeting of the International Geological Congress will be held in London in September next on the 17th and following days. An Organizing Committee has nominated the following Officers:—*Honorary President*, Prof. T. H. Huxley, D.C.L., LL.D., F.R.S. *President*, Prof. J. Prestwich, M.A., F.R.S. *Vice-Presidents*, the President of the Geological Society, the Director-General of the Geological Survey, and Prof. T. M'Kenny Hughes, M.A. *Treasurer*, F. W. Rudler. *General Secretaries*, J. W. Hulke, F.R.S., and W. Topley. Steps are being taken to enlist the cooperation of all persons interested in Geology

and the allied branches of science. Particulars will be immediately announced by the Committee.

Fellows of the Society are invited to join the Congress and to assist in making the Meeting a success.

The following communications were read :—

1. "On the Correlation of some of the Eocene Strata in the Tertiary Basins of England, Belgium, and the North of France." By Prof. Joseph Prestwich, M.A., F.R.S., F.G.S.

Although the relations of the several series have been for the most part established, there are still differences of opinion as to the exact relation of the Sable de Bracheux and of the Soissonnais to the English series; of the Oldhaven Beds to the Woolwich series; and of the London Clay and Lower and Upper Bagshots to equivalent strata in the Paris basin. The author referred to the usual classification of the Eocene Series, and proceeded to deal with each group in ascending order.

The *Calcaire de Mons* is not represented in England, but may be in France by the Strontianiferous marls of Meudon. It contains a rich molluscan fauna, including 300 species of Gasteropods, many of which are peculiar, but all the genera are Tertiary forms. The *Heersian* are beds of local occurrence, and the author sees no good reason for separating them from the *Lower Landenian* or *Thanet Sands*. He gave reasons for excluding the *Sands of Bracheux* from this group. Out of 28 Pegwell-bay species, 10 are common to the Lower Landenian, and 5 to the Bracheux Sands, which present a marked analogy with the Woolwich Series. These Sands of Bracheux are replaced in the neighbourhood of Paris by red and mottled clays. Out of 45 species at Beauvais only 6 are common to the Thanet Sands and 10 to the Woolwich Series. Out of 75 species in the *Woolwich and Reading Beds* 19 occur in the Bracheux Beds, if we add to these latter the Sands of Chalons-sur-Vesles.

Respecting the *Basement Bed* of the London Clay (*Oldhaven Beds* in part), the author would exclude the Sundridge and Charlton fossils, which should be placed on a level with the Upper Marine Beds of Woolwich. He allowed that the former were deposited on an eroded surface, but this involves no real unconformity, whilst the palæontological evidence is in favour of this view, since out of 57 species in the Sundridge and associated beds, only 16 are common to the London Clay. He therefore objected to the quadruple division. Either the Oldhaven should go with the Woolwich or with the Basement Bed. He admitted that the term "Basement Bed" is objectionable, and preferred Mr. Whitaker's term for the series, as he would limit it.

The *Lower Bagshot Sands*.—The author would call "London Sands," whose Belgian equivalent is the Upper Ypresian, and the French the Sands of Cuise-la-Motte, forming the uppermost series of the Lower Eocene. A group of fossils has been discovered in the Upper Ypresian sands of Belgium, which leaves no doubt of their being of Lower Eocene age, and consequently the Lower Bagshots must be placed upon the same horizon. There is no separating line of erosion between the London Clay and the Lower Bagshots, the

upper part of the former is sandy, and the lower part of the latter frequently argillaceous. Similarly no definite line can be drawn between the Upper and Lower Ypresian; but in both countries this series is separated from overlying beds by a well-marked line of erosion. So also in France the base of the *Calcaire Grossier* (Bracklesham Beds) is a pebbly greensand resting on an eroded surface of the Sands of the Cuise-de-la-Motte. In Belgium, in Whitecliff Bay, and in the Bagshot district the Upper Eocene rests upon an eroded surface of the Lower Eocene. Subjoined is the author's proposed classification of the Eocene :—

	England.	Belgium.	France (Paris Basin).
Upper.	*a*. Barton Beds.	*a*. Wemmelian.	*a*. Sables Moyens or Grès de Beauchamp.
Upper.	*b*. Bracklesham Beds. = Upper and *b**. Middle Bagshots.	Lakenian and Bruxellian.	*b*. Upper Calcaire Grossier *b**. Glauconie Grossière.
Lower.	Wanting.	Paniselian	Sands of Cuise-la-Motte.
Lower.	London Sands = Lower Bagshot.	Upper Ypresian.	
Lower.	London Clay.	Lower Ypresian.	Wanting.
Lower.	Basement or Oldhaven Beds.	?	Sables Inférieurs of the Soissonnais, including the Marls and Sands of Rilly, the 'Lignites' and Sands of Bracheux.
Lower.	Woolwich and Reading Beds.	Upper Landenian.	
Lower.	Thanet Sands	Lower Landenian and Heersian.	Sands of St. Omer, Douai, and La Fère.
Lower.	Wanting.	Calcaire de Mons.	Strontianiferous Marl of Meudon?

2. "On the Cambrian and Associated Rocks in North-west Caernarvonshire." By Prof. J. F. Blake, M.A., F.G.S.

After referring to the published views of Professor Sedgwick, Sir A. C. Ramsay, and the Geological Survey, Professors Hughes and Bonney and Dr. Hicks concerning the area in question and especially as to the presence or absence of Precambrian rocks, the author gave an account of his own explorations and their results, the principal of which were the following.

In the Bangor and Caernarvon area three distinct conglomerates had been confounded. The only one that showed distinct unconformity on the underlying rock was of Arenig (Ordovician) age. The rocks of the southern and central portion of the area were essentially of igneous origin and might be distinguished into two groups, the southern probably intrusive, the northern certainly eruptive. There is no evidence to show what interval of time elapsed between the production of these two groups, nor which of them is the earlier, although the author regards it as more probable that the southern mass is of the earlier date and overlain by the northern portions. The Bangor beds are derived from the denudation of the

volcanic series, and of rocks which may have been associated with it, and they contain a series of conformable conglomerates of which the great conglomerates near Bangor are members. They are the continuation of the Cambrian rocks seen to the east, and have not undergone any serious alteration. The porphyries of Llyn Padarn and Moel Tryfaen are contemporaneous lava-flows in the midst of the Cambrian series, the overlying conglomerates being derived from them and from the sedimentary Cambrian rocks to the west; and hence there is no certain proof of there being any Precambrian rocks in the whole district, though it is probable that the rock near Caernarvon belongs to an epoch distinct from and anterior to the Cambrian.

II.—January 11, 1888.—Prof. J. W. Judd, F.R.S., President, in the chair.—The following communications were read:—

1. "On the Law that governs the Action of Flowing Streams." By R. D. Oldham, Esq., F.G.S.

The author, after describing how his attention was drawn to the subject, proceeded to an investigation of the law that governs the action of a flowing stream. Having accepted as a fundamental principle that the velocity of a stream will always tend to become such as is just sufficient to transport the solid burden cast on to the stream, and pointed out that the principle is almost axiomatic in its nature, he finds that, where untrammelled by exterior conditions, a stream will be alternately confined to a single, well-defined, deep channel, and spread out into a number of ill-defined, shallow channels, the former being defined as a "reach," the latter as a "fan," that the gradient in the "reach" is less than in the "fan," and that both "reach" and "fan" will continually be encroaching at their upper ends, and being encroached upon at their lower ends.

After detailing some general considerations which show that what should occur according to hypothesis does actually occur in nature, he indicated that the accurate and detailed levels taken in connexion with the Ganges Canal do actually show this alternation of "reach" and "fan," that the gradients are higher in the latter, as they should be, and that the records of the Canal show the retrogression of "fan" and "reach" demanded by the hypothesis.

Accepting this agreement of fact with hypothesis as proof of the correctness of the latter, it follows that the fundamental principle on which it is founded is correct, and that, in the absence of interfering causes of greater potency, it is the coarseness or fineness of the débris cast upon a stream that will determine its gradient and velocity, and not, as stated in text-books, the velocity of a stream that will determine its gradient and the coarseness of the débris transported by it:—a conclusion that might be arrived at independently, from the fact that it is in the upper reaches of a stream, where coarse débris prevails, that high velocities of current prevail, while in the lower reaches, where the débris is finer in grain, the velocity of current is also diminished.

2. "Supplementary Notes on the Stratigraphy of the Bagshot

Beds of the London Basin." By the Rev. A. Irving, B.Sc., B.A., F.G.S.

This paper contained the results of field-work during the year 1887. Additional notes on the stratigraphy of the Bracknell and Ascot Hills were given, justifying the reading of the country as shown in figs. 1 and 2 of the author's last paper (Q.J.G.S. August, 1887), the examination of this line of country having been extended as far as Englefield Green. Sections of the beds of the Middle Group as they crop out at Cæsar's Camp, Swinley Park, Ascot, and Sunningdale, were described and correlated with the 76 feet of beds which constitute that group in the Well-sections at Wellington College.

The stratigraphy of the hills known as Finchampstead Ridges has been worked out from numerous sections on their flanks; and the strata of the Bearwood Hills were correlated directly with them.

All along the northern margin a general attenuation of (*a*) the Lower (fluviatile) Sands, and of (*b*) the Middle (green earthy) Sands was shown to occur, and in some places on the northern margin they are found to have entirely thinned away, admitting of distinct overlap at more than one horizon.

The second part of the paper dealt with the Highclere district, where the author believes he has established the full succession of the three stages of the Bagshot formation, a section being given across the valley south of Highclere Station, showing the succession of the whole Eocene series (with the *Ostrea bellovacina*-bed for its base) as it is developed there.

Some important conclusions were drawn as to the Tertiary physiography of the South of England; and the revised tabulation of the Tertiaries put forward by Prof. Prestwich at the Society's last meeting was referred to as supporting some of the main points for which the author has contended.

3. "The Red-Rock Series of the Devon Coast Section." By the Rev. A. Irving, B.Sc., B.A., F.G.S.

From a recent examination of this section, and from the facts furnished by Mr. Ussher's paper (Q.J.G.S. vol. xxxii. pp. 367 *et seq.*), the author has arrived at the conclusion that the series of red rocks between the Lias to the east of Seaton and the Carboniferous of Devon, formerly described under the title of "New Red Sandstone," cover the period of geologic time which that term signified, and that the lower members of the series belong, not to the Trias, but to the Permian or Post-Carboniferous.

He considered that at the base of the Budleigh-Salterton pebble-bed there is a physical break of as much significance as that between the Trias and the Permian of the Midlands. From this point eastwards the Triassic system is represented by a series of rocks quite comparable with the Bunter and Keuper of the Midlands, the Bunter being here represented by the Middle Division (about 200 feet thick) and the Upper Division of Prof. Hull.

These pass under the basement sandstone-series of the Keuper below High Peak and Peak Hills, are brought up again by faulting at Sidmouth, and dip beneath the Keuper again east of the Sid,

from which point eastwards the whole Keuper Division is exposed, with quite a normal facies, as seen in the Midlands, in Central Germany (Thüringen, Jena), and in the Neckar Valley.

In the marls which underlie the Budleigh-Salterton Pebble-bed, he recognized the equivalents of the Permian Marls of Warwickshire and Nottinghamshire, and of the Zechstein Marls of Germany. These pass, by a gradual transition, through Sandstones, becoming more and more brecciated, into the great brecciated series of Dawlish and Teignmouth, which were regarded as the equivalents of the great Permian breccias of the west of England, of Ireland, and of the Lower Rothliegendes of Germany.

All the rocks below the Budleigh-Salterton Pebble-bed were regarded as the assorted materials furnished by the detritus of the Palæozoic mountain-region of Devon, Cornwall, and Brittany, and as representing the waste and degradation of that region, deposited on the mountain-flanks and in land-locked bays during Post-Carboniferous times, the marls being compared with the Nyirok of the Austrian geologists.

CORRESPONDENCE.

ERRATIC BOULDERS.

Sir,—Your notice of Prof. Hull's paper on "Boulder Stones," read before the British Association last year, recalls my attention to an interesting example of a boulder I came across during a geological excursion in the Grantham district (Sheet 73) some four or five years ago, which I believe exceeds the dimensions of the largest given by Prof. Hull. I had stayed the night at the village of Marston, about five or six miles west of Ancaster, and was making my way in the early morning towards the quarries of our noted Lincolnshire freestone, situate at the latter village, when I noticed a rough accommodation road metalled with Lincolnshire Oolite. This struck me as rather strange, there being several quarries in the Marlstone much nearer at hand. I followed it up, and ultimately found the quarry from which the stone was obtained, a quarry in Lincolnshire Oolite! at least five miles further west than one would expect to find such a thing. The quarry, on examination, proved to be excavated in a huge boulder stranded on a hill of Middle Lias clay capped by Marlstone. The boulder was almost covered by a very tough chocolate-coloured Boulder-clay, containing Lias fossils, and grassed over. A roadway was cut into it for a distance of twelve or fifteen yards (writing from memory). The definite outline of boulder was obscured in all directions except the entrance to the quarry, where the workmen had cut down to the Lias below, the lines of bedding dipped about 20 per cent. N.W. This stone had probably travelled from the neighbourhood of Ancaster, five miles east, where the line of cliff (escarpment of the Oolites) is cut back and forms a sort of gorge; this is the nearest point it could possibly have come from.

W. D. Carr.